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SPACE SHUTTLE INTEGRATED VEHICLE AERODYNAMIC INTERFERENCE HEATING TEST (NASA JSC TEST IH-97)

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Calspan Field Services, Inc.

December 1982

Final Report for Period August - December 1982

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Wind tunnel tests were conducted on the 0.0175 scale 60-OTS Integrated Space Shuttle Vehicle in the von Karman Gas Dynamics Facility Tunnel A. The objectives were to obtain heating data in locations where developmental flight instrumentation (DFI) had been placed on the full scale vehicle and to obtain validation data for the aeroheating design methodology. Data were obtained over the Mach range of 2.25 to 4.00 at free stream unit Reynolds numbers of 3.7×10^6 to 5.7×10^6 per foot. Model attitude was varied over the range +5 to -5 degrees angle of attack and +6 to -6 degrees angle of side slip.

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APPENDIXES

NOMENCLATURE

a_1, a_2, a_3	Denote constant terms used to calculate R
ALPHA	Model angle of attack, deg
ALPHA-SECTOR, α_s	Tunnel sector angle, deg
b	Model wall thickness, ft
BETA	Model angle of sideslip, deg
c	Model wall specific heat, $\frac{\text{Btu}}{\text{lbm-°R}}$
C.R.	Center of rotation, axis about which model is pitched in the tunnel
C_1	Schmidt-Boelter calibration contant, mv/Btu/ft^{2}sec, Table 5
DELTBF	Body flap deflection angle, deg
DELTAE	Elevon deflection angle, deg
DELTSB	Speed brake deflection angle, deg
DTW/DT	Derivative of the model wall temperature with respect to time, °R/sec.
E	Schmidt-Boelter Gage output, mv
GAGE NO	Schmidt-Boelter Gage identification number
H(TR)	Heat-transfer coefficient based on TR, $\frac{\text{QDOT}}{\text{TR-TW}}$, $\frac{\text{Btu}}{\text{ft}^2\text{-sec°R}}$
H(TT)	Heat-transfer coefficient based on TT, $\frac{\text{QDOT}}{\text{TT-TW}}$, $\frac{\text{Btu}}{\text{ft}^2\text{-sec-°R}}$
H(0.95TT)	Heat-transfer coefficient based on 0.95 TT $\frac{\text{QDOT}}{\text{(0.95TT)-TW}}$, $\frac{\text{Btu}}{\text{ft}^2\text{-sec-°R}}$

H(RTT)	Heat-transfer coefficient based on RTT $\frac{QDOT}{RTT-TW}$, $\frac{Btu}{ft^2\text{-sec-}°R}$
HREF, H(REF)	Reference heat-transfer coefficient based on Fay-Riddell theory, Btu/ft^2-sec-°R, see Appendix III
L_S, L_T	Axial reference length, in. (see Fig. 2)
M_e	Mach number at boundary layer edge
MACH NO., M	Free stream Mach number
MODEL	Model configuration
MU	Free-stream viscosity, lb-sec/ft^2
N_x,N_y,N_z	Direction cosines of the outward unit normal vector at each measurement location on the External Tank and SRB's. See Tables 3 and 4
OTS	Orbiter, external tank, and both solid rocket boosters
P	Free-stream pressure, psia
PT	Tunnel stilling chamber pressure, psia
Q	Free-stream dynamic pressure, psia
QDOT	Heat-transfer rate, Btu/ft^2-sec
RUN	Data set identification number
r	Recovery factor
R	Radius or analytical temperature ratio, TR/TT
RN	Reference nose radius for HREF and STFR calculations, (RN = 0.0175 FT).
RE RE/FT	Free-stream Reynolds number per foot, ft^{-1}
RHO	Free-stream density, lbm/ft^3
ROLL-SECTOR, ϕ	Tunnel sector angle of roll, deg

SRB	Solid Rocket Booster
STFR	Theoretical stagnation point Stanton number for a 0.0175-ft radius sphere calculated from Fay-Riddell theory
S.F.	Schmidt-Boelter gage scale factor the reciprocal of C_1, Btu/ft^2-sec/mv
T	Temperature, °R Free-stream static temperature, °R
TC-NO	Thin skin thermocouple identification number
T_e	Temperature at the edge of the boundary layer, °R
THETA, θ	Model circumferential measurement coordinate, deg (see Fig. 2)
TI	Model initial wall temperature prior to injection in the tunnel, °R
TR	Boundary layer recovery temperature, °R
TT	Free-stream total temperature, °R
TW	Model wall temperature, °R
V	Free-stream velocity, ft/sec
X	Model axial coordinate, in.
X/L	Nondimensionalized axial location
YAW	Model angle of yaw, deg
δ	The included angle between the free stream velocity vector and local unit normal to the model surface, deg
γ	Ratio of specific heats
ρ	Model wall density, lbm/ft^3

CONFIGURATION - OTS + Tr + TVC

*OTS	0.0175 scale orbiter, External Tank, right and left Solid Rocket Boosters (SRB)
Tr	Transition strips (SRB's and Orbiter)
TVC	Thrust Vector Control Pods on left SRB

*OTS B_{62} C_{12} M_{16} W_{116} E_{52} V_8 R_{18} F_{10} T_{38} S_{26}

B_{62} - Fuselage

C_{12} - Canopy

M_{16} - OMS Pod

W_{116} - Wing

E_{52} - Elevon

V_8 - Vertical tail

R_{18} - Rudder

F_{10} - Body flap

T_{38} - External Tank (Spike Hose)

S_{26} - Solid Rocket Booster

1.0 INTRODUCTION

The work reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 921E01, Control Number 9E01, at the request of the Johnson Space Center (NASA-JSC(ES3)), Houston, Texas. The NASA-JSC (ES3) program manager was Mrs. Dorothy B. Lee and the Rockwell International test engineers were Mr. C. R. Leef, Mr. John Marroquin, and Mr. E. C. Knox. The results were obtained by Calspan Field Services, Inc./AEDC Division, operating contractor for the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Station, Tennessee. The tests were performed in the von Karman Gas Dynamics Facility (VKF), under AEDC Project No. C767VA.

The test was performed in the 40-in. Supersonic Wind Tunnel (A) at the von Karman Gas Dynamics Facility (VKF) during the time period October 18-19, 1982.

The configuration tested was the 1.75 percent scale 60-OTS Integrated Space Shuttle model. The test was divided into two phases. The objective of the first phase (PHASE A) was to obtain heating data in locations where developmental flight instrumentation (DFI) had been placed on the full scale External Tank, Solid Rocket Boosters and associated hardware and support structure. Data were obtained over the Mach range 2.25 to 4.00 at free stream unit Reynolds numbers of 3.7×10^6 to 5.7×10^6 per foot. Nominal launch pitch and yaw attitudes from STS 1-4 were duplicated during the course of the test. The objective of the second phase (PHASE B) was to obtain validation data for the STS integrated vehicle aeroheating design methodology as well as heating data on and around the external TVC Pod located on the skirt of the left SRB. Data were recorded generally at free stream Mach numbers of 3.00 and 4.00 and free stream unit Reynolds numbers of 3.7×10^6 and 4.00×10^6 per foot respectively. The model attitude was varied over the range +5 to -5 degrees angle of attack and +6 to -6 degrees angle of yaw.

A summary of the test data transmitted is shown in Table 1. Inquiries to obtain copies of the test data should be directed to NASA-JSC (ES3), Houston, Texas 77058. A microfilm record has been retained in the VKF at AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel A is a continuous, closed-circuit, variable density wind tunnel with an automatically driven flexible-plate-type nozzle and a 40- by 40-in. test section. The tunnel can be operated at Mach numbers from 1.5 to 6 at maximum stagnation pressures from 29 to 200 psia, respectively, and stagnation temperatures up to 750°R (M = 6). Minimum operating pressures range from about one-tenth to one-twentieth of the maximum at each

Mach number. The tunnel is equipped with a model injection system which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel and airflow calibration information may be found in Ref. 1. A schematic view of Tunnel A and the model injection system is shown in Fig. 1, Appendix I.

2.2 TEST ARTICLE

The 60-OTS model is a 0.0175 scale thin skin thermocouple model of the Rockwell International Vehicle 5 Configuration (Fig. 2). The 60-OTS configuration tested was composed of the following Rockwell component buildup: OTS = B_{62} C_{12} M_{16} W_{116} E_{52} V_8 R_{18} F_{10} T_{38} S_{26}. The model was constructed of 17-4 PH stainless steel with a nominal skin thickness of 0.030 in at all instrumented areas except the intertank area. A new instrumented corrugated intertank, Fig. 2b, was fabricated for the test. Effective skin thickness of this section was 0.040 in. In addition, the external tank was configured with the 30 deg/10 deg spiked nose tip, (Fig. 2b). For Phase B, instrumented Thrust Vector Control Pods (TVC) (Fig. 2d) were added to the aft skirt of the left SRB.

Orbiter elevon deflection angles of zero and 10 degrees were run throughout the test. The orbiter speed brake and body flap were set at zero degrees deflection.

Boundary layer trips were used on the orbiter and each SRB to generate a turbulent boundary layer (Fig. 2e). The trips consisted of 0.025 in-diam balls spaced on 0.075 in. centers. Trips for the SRBs were attached to form fitted steel rings while trips for the orbiter were attached to a steel strip. Axial locations of the trips on the SRBs were at X/L = 0.033 and X/L = 0.040 for the orbiter.

An installation photograph of the 60-OTS model in Tunnel A is shown in Fig. 3a and an installation sketch of the model is shown in Fig. 3b.

2.3 TEST INSTRUMENTATION

The instrumentation, recording devices, and calibration methods used to measure the primary tunnel and test data parameters are listed in Table 2a along with the estimated measurement uncertainties. The range and estimated uncertainties for primary parameters that were calculated from the measured parameters are listed in Table 2b.

The 60-OTS model was instrumented with chromel-constantan thin-skin thermocouples (30 gage wire) and 0.050 in.-diam thermopile Schmidt-Boelter heat transfer gages. Schmidt-Boelter gage instrumentation was placed in locations not instrumented on previous space shuttle tests such as struts, cable trays and other support structure and protuberances.

The External Tank was instrumented with 141 thin skin thermocouples and 28 Schmidt Boelter gages. Instrumentation was composed of gages and thermocouples carrying the 600, 700, 2000 and 5000 series designation numbers. Instrumentation location is depicted in Fig. 4a for the External Tank and in Figs. 4b-4f for the support hardware, i.e., bipod strut, cable tray, thrust struts, etc.

The SRBs were instrumented as follows: the right SRB (Fig. 5a) contained 30 thin skin thermocouples and 7 Schmidt-Boelter gages. The left hand SRB (Fig. 5b) contained 32 thin skin thermocouples and 12 Schmidt-Boelter gages - this included 5 Schmidt-Boelter gages installed on the TVC pods (Fig. 5c). Right SRB instrumentation was composed of the 3000 series designation numbers while the 4000 series designation pertained to the left SRB. Instrumentation location on associated SRB hardware (support struts,kick rings, etc.) is illustrated in Fig. 5d-5i.

Instrumentation for Phase A consisted of 174 thin skin thermocouples and 41 Schmidt-Boelter gages from the ET and SRBs, while Phase B instrumentation consisted of 164 thin skin thermocouples and 46 Schmidt-Boelter gages. Instrumentation locations for Phase A and B are given in Tables 3 and 4, respectively.

The Schmidt-Boelter gages were developed by Medtherm Corporation of Huntsville, Alabama. The gage is a direct reading heat flux gage with a chromel-constantan thermocouple vapor deposited on the gage surface. The addition of the thermocouple to the gage allows measurement of surface temperature and heat flux simultaneously. The principle of operation of the gage is based on axial heat conduction from the gage surface to a heat sink embedded within the gage. The difference in temperature between two points along the path of heat flow from the surface to the sink is proportional to the heat transferred and therefore the heat flux absorbed. At two such points the Medtherm gages have thermocouple junctions which form a differential thermoelectric circuit providing a self generating EMF between the two output leads directly proportional to the heat transfer rate. The gages were built in place and are therefore an integral part of the 60-OTS model. Schmidt-Boelter gage calibrations were performed by the Medtherm corporation. The resulting calibration constants are presented in Table 5.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS

A summary of the nominal test conditions for Phase A and Phase B is given below:

M	PT, psia	TT, °R	P, psia	T, °R	Re/ft x 10^{-6}
2.24	23	637	2.0	318	4.2
2.50	26	649	1.5	289	4.0
2.75	31	650	1.2	258	4.1
3.00	34	675	0.9	240	3.8
3.00	36	723	1.0	256	3.7
3.00	52	683	1.4	243	5.7
3.24	45	725	0.9	234	4.0
3.50	55	729	0.7	211	4.2
3.77	61	738	0.6	192	4.0
4.00	72	738	0.5	174	4.1

Data were obtained on the External Tank and Solid Rocket Boosters over the attitude range -5 to +5 degrees angle of attack and -6 to 6 degrees angle of yaw. Yaw angles were achieved by pitching and rolling the model.

A test summary showing the configuration tested and the variables for each run is presented in Table 6.

3.2 TEST PROCEDURES

3.2.1 General

In the VKF continuous flow wind tunnels (A, B, C), the model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door. When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank and the safety door seals the tunnel from the tank area. After the model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, and the model is injected into the airstream. After the data are recorded, the model is retracted into the tank and the sequence is reversed with the tank being vented to atmosphere to allow access to the model in preparation for the next run.

3.2.2 Data Acquisition

The initial step prior to recording the test data was to cool the model uniformly to approximately 15°F with cooled high pressure air. This was accomplished by positioning the model in the Tunnel A cooling manifold and bathing the model in chilled high pressure air from a Vortex generator (Hilsch Vortex tube, Ref. 2). The cooling manifold, which is normally located to the side of the model, was modified such that it was supported off the tank floor (Fig. 6). This modification allowed the model attitude to be set while model cooling was being performed. The model was then injected directly out of the cooling environment into the tunnel flow. (This procedure allowed the attainment of much colder model wall initial temperatures.) When the model reached tunnel centerline, it was translated forward to clear the area of tunnel induced shock impingement. The instrumentation outputs were scanned approximately 15 times per second, starting just before the model reached tunnel centerline and continuing until the model reached the full forward position in the tunnel (about 5 seconds after centerline). The model was then retracted into the tank area below the tunnel and the cooling cycle begun to cool the model to an isothermal state.

The model data were acquired using a 256 channel analog to digital multiplexing system. These measurements as well as tunnel flow measurements, model attitude measurements and time were processed by the Random Access Data Acquisition System (RADS) PDP-11 minicomputer and recorded on disc memory for transmission to the facility computer (DEC-10) for data reduction.

3.3 DATA REDUCTION

3.3.1 Tunnel Parameters

Measured stilling chamber pressure and temperature and the calibrated test section Mach number are used to compute the free stream parameters.

3.3.2 Thin Skin Measurements

The reduction of thin skin temperature data to coefficient form normally involves only the calorimeter heat balance for the thin skin as follows:

$$\mathrm{QDOT} = \rho bc\left(\mathrm{DTW/DT}\right) \tag{1}$$

$$\mathrm{H(TR)} = \frac{\mathrm{QDOT}}{\mathrm{TR\text{-}TW}} = \frac{\rho bc\left(\mathrm{DTW/DT}\right)}{\mathrm{TR\text{-}TW}} \tag{2}$$

Thermal radiation and heat conduction effects on the thin-skin element are neglected in the above relationship and the skin temperature response is assumed to be due to convective heating only. It can be shown that for constant TR, the following relationship is true:

$$\frac{d}{dt}\ \ln\left[\frac{\mathrm{TR\text{-}TI}}{\mathrm{TR\text{-}TW}}\right] = \frac{\mathrm{DTW/DT}}{\mathrm{TR\text{-}TW}} \tag{3}$$

Substituting Eq. (3) in Eq. (2) and rearranging terms yields:

$$\frac{\mathrm{H(TR)}}{\rho bc} = \frac{d}{dt}\ \ln\left[\frac{\mathrm{TR\text{-}TI}}{\mathrm{TR\text{-}TW}}\right] \tag{4}$$

By assuming that the value of H(TR)/ρbc is a constant, it can be seen that the derivative (or slope) must also be constant. Hence, the term

$$\ln\left[\frac{\mathrm{TR\text{-}TI}}{\mathrm{TR\text{-}TW}}\right]$$

is linear with time. This linearity assumes the validity of Eq. (2) which applies for convective heating only. The evaluation of conduction effects will be discussed later.

The assumption that H(TR) and c are constant is reasonable for this test although small variations do occur in these parameters. The variations of H(TR) caused by changing wall temperature and by transition movement with wall temperature are trivial for the small wall temperature changes that occur during data reduction. The value of the model material specific heat, c, was computed by the relation

$$c = 0.0797 + (5.556 \times 10^{-5})\mathrm{TW}, \ \text{(17-4 PH stainless steel)} \tag{5}$$

The maximum variation of c over the curve fit was less than 1.5 percent. Thus, the assumption of constant c used to derive Equation 4 was reasonable. The value of density used for the 17-4 PH stainless steel skin was $\rho = 490 \text{ lbm/ft}^3$, and the skin thickness, b, for each thermocouple is listed in Table 3 for Phase A and Table 4 for Phase B.

The right side of Equation 4 was evaluated using a linear least squares curve fit of 15 consecutive data points to determine the slope. The curve fit was started at approximately the time the model arrived on tunnel centerline. Data acquisition and curve fitting were continued for about 5 seconds after centerline; i.e., until the model reached the full forward position in the tunnel. H(TR) was then calculated for each thermocouple from the resulting slopes and the appropriate values of ρbc;

$$H(TR) = \left(\rho bc\right)\frac{d}{dt} \ln\left[\frac{TR-TI}{TR-TW}\right] \tag{6}$$

Reduction of the final data; i.e., the values listed in the tabulated data, was delayed in time until all thermocouples influenced by the tunnel induced shock had been translated forward out of this region of tunnel flow. For the External Tank, reduction of those thermocouples between $0 \leq X/L \leq 0.2$ was reduced at centerline and those thermocouples between $0.2 \leq X/L \leq 1.00$ were delayed approximately 2.5 seconds after model arrival on tunnel centerline. For the SRBs, data reduction of thermocouples located between $0 \leq X/L \leq 0.113$ was started at centerline and delayed approximately 2.5 seconds for thermocouples located between $0.113 \leq X/L \leq 1.00$.

To investigate conduction effects, a second value of H(TR) was calculated one second later than the value under consideration for final tabulated data. A comparison of these two values was used to identify those thermocouples that were significantly influenced by conduction or system noise. In addition, timewise variation of H(TR) was monitored to insure that the final data were reduced during a time period where H(TR) was constant. Those measurements significantly affected were then deleted from the final data. In general, conduction and/or noise effects were found to be negligible.

3.3.3 Schmidt-Boelter Measurement

Measurements obtained from the Schmidt-Boelter gages; i.e., gage output, E, and surface thermocouple output, were used to calculate the incident heat flux (QDOT), wall temperature (TW) and heat transfer coefficient in the following manner. The gage output and surface thermocouple were sampled five consecutive times and then averaged. This procedure began when the model was at approximately tunnel centerline and continued until translation to the full forward position in the tunnel was achieved (about 5 seconds; i.e., the same fashion as the thin skin thermocouple data). The average values of the gage output E were then related to the incident heat flux (QDOT) through the gage scale factor.

$$QDOT = (S.F.)(E) \tag{7}$$

The scale factor is equal to the reciprocal of the gage calibration constants (C_1) listed in Table 5.

$$S.F. = 1/C_1 \tag{8}$$

Using the same averaging procedure an average value of gage surface thermocouple output was obtained. The average values were then related to the wall temperature (TW) through the use of a fifth degree polynomial curve fit of the NBS (National Bureau of Standards) tables for a chromel-constantan thermocouple. The heat transfer coefficient for each average value was calculated from the following equation:

$$H(TR) = \frac{QDOT}{(TR-TW)} \tag{9}$$

Final data reduction, i.e., those data listed in the final data package, was delayed in time for the Schmidt-Boelter gages in the same fashion as used for the thin skin thermocouple data. Again this was done to insure that those gages which might be influenced by the tunnel induced shock were out of this region of tunnel flow. Timewise variation of H(TR) versus time for the various Schmidt-Boelter gages was monitored to insure that the final data were reduced during a time period where H(TR) was constant. For cases where either the gage output or surface thermocouple was faulty, that particular measurement was deleted and likewise the calculation of heat transfer coefficient. The remaining valid measurement was then tabulated.

3.3.4 Recovery Temperature and R Factor

The maximum available tunnel stagnation temperature for each Mach number tested is listed in Section 3.1. With these relatively low stagnation temperatures, the difference between the model wall temperature and recovery temperature was generally small, even in regions of peak heating. This small temperature difference caused the calculation of the heat-transfer coefficient to be very sensitive to deviations from the actual recovery temperature. Since the actual value of the recovery temperature (TR) at each measurement location is not known, three assumed values of TR are used to calculate the local heat transfer coefficients. They are TR = TT, 0.95 TT, and RTT where R is defined by the analytic temperature ratio $\frac{TR}{TT}$. The analytic method for determining R was developed by Rockwell International. In this method the following relationships were assumed:

$$R = \frac{TR}{TT} \tag{10}$$

and

$$TR = T_e \left(1 + \frac{\gamma-1}{2} r M_e^2\right) \qquad (11)$$

$$r = 0.898 \text{ for turbulent flow}$$

with r being the recovery factor and the subscript e identifying local properties at the boundary-layer edge. From these relationships, the temperature ratio can be defined as:

$$R = \frac{1 + 0.2\, r\, M_e^2}{1 + 0.2\, M^2} \qquad (12)$$

which is a function of the recovery factor and the local Mach number. The local Mach number can be written

$$M_e = M_e\ (M,\ \delta) \qquad (13)$$

where δ is the local surface angle of attack.

The local Mach number can be approximated by using tangent cone flow theory, and was used in Equation (12) to give R as a function of M and δ. Calculations of R were made for several values of M and δ, and the results were curve fit by Rockwell International. The following equation resulted

$$R(M,\ \delta) = a_1 + a_2 \cdot (\sin\ \delta)^{a_3} \qquad (14)$$

where a_1 a_2 and a_3 are constants for a particular Mach number. Turbulent values of a_1 a_2 and a_3 for this test were provided by Rockwell International and are as follows:

M	a_1	a_2	a_3
2.25	0.950	$1.0-a_1$	2.322
2.50	0.944		2.275
2.75	0.938		2.222
3.00	0.934		2.165
3.25	0.930		2.115
3.50	0.927		2.070
3.75	0.925		2.015
4.00	0.922		1.965

The angle δ is the included angle between the free stream velocity vector and the local normal to the model surface. δ was computed using the following equation

$$\delta = \sin^{-1}\left\{\left[N_x \cos\alpha_s - N_y \sin\alpha_s \sin\phi + N_z \sin\alpha_s \cos\phi\right] (-1)\right\}$$

where N_x, N_y and N_z are the direction cosines for the local unit normal. Values of N_x, N_y and N_z for each thin skin thermocouple and Schmidt-Boelter gage is tabulated in Table 3 for Phase A and Table 4 for Phase B.

For values of $\delta \leq 0$ $R \equiv a_1$.

For R values > 1.0 $R \equiv 1.00$

Values of heat transfer coefficient H(TT), H(0.95TT) and H(RTT) were normalized using the Fay-Riddell stagnation point heat transfer coefficient H(REF). The calculation of H(REF) was based on a hemispherical nose radius of 0.0175 ft model scale (1.0 ft full scale). Definition of the calculation of H(REF) is given in Appendix III.

3.4 UNCERTAINTY OF MEASUREMENT

In general, instrumentation calibrations and data uncertainty estimates were made using methods recognized by the National Bureau of Standards (NBS). Measurement uncertainty is a combination of bias and precision errors defined as:

$$U = \pm(B + t_{95}S)$$

where B is the bias limit, S is the sample standard deviation and t_{95} is the 95th percentile point for the two-tailed Student's "t" distribution (95-percent confidence interval), which for sample sizes greater than 30 is taken equal to 2.

Estimates of the measured data uncertainties for this test are given in Table 2a. The data uncertainties for the measurements are determined from in-place calibrations through the data recording system and data reduction program.

Propagation of the bias and precision errors of measured data through the calculated data was made in accordance with Ref. 3 and the results are given in Table 2b.

4.0 DATA PACKAGE PRESENTATION

Convective heat-transfer-rate distributions were obtained on a 0.0175 scale model of the Space Shuttle Integrated Vehicle. The final tabulated and photographic data were transmitted to NASA-JSC and Rockwell International with this report. Examples of the tabulated data for the thin skin and Schmidt-Boelter gage measurements are presented in Appendix IV. A photographic log correlating roll number and run number is presented in Table 7.

Representative data from the top centerline of the External Tank (θ=0 deg) are presented in Figs. 7 and 8 for M = 3.00 and 4.00, respectively. The data from the current test (IH-97) are compared with data from previous entries in Tunnel A i.e., IH 72 and IH-85 as well as turbulent theory of Refs. 4 and 5. The data pertain to the integrated vehicle while the theory was calculated for interference free tank alone. Agreement of the IH-97 with previous data and theory (upstream of interference regions) is considered good for validation of the basic results.

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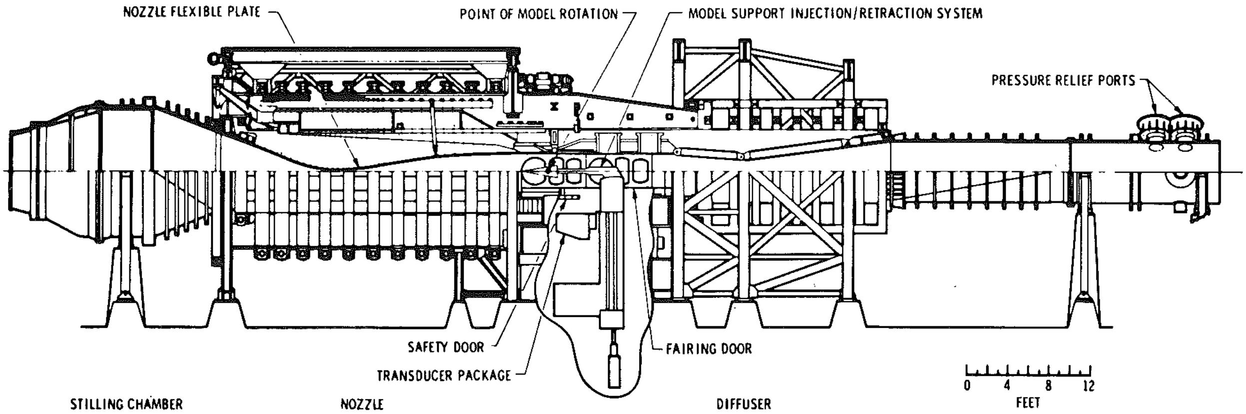
4. DeJarnette, Fred R. "Calculation of Inviscid Surface Streamlines on Shuttle-Type Configurations, Part I - Description of Basic Method." NASA CR-111921, August 1971.

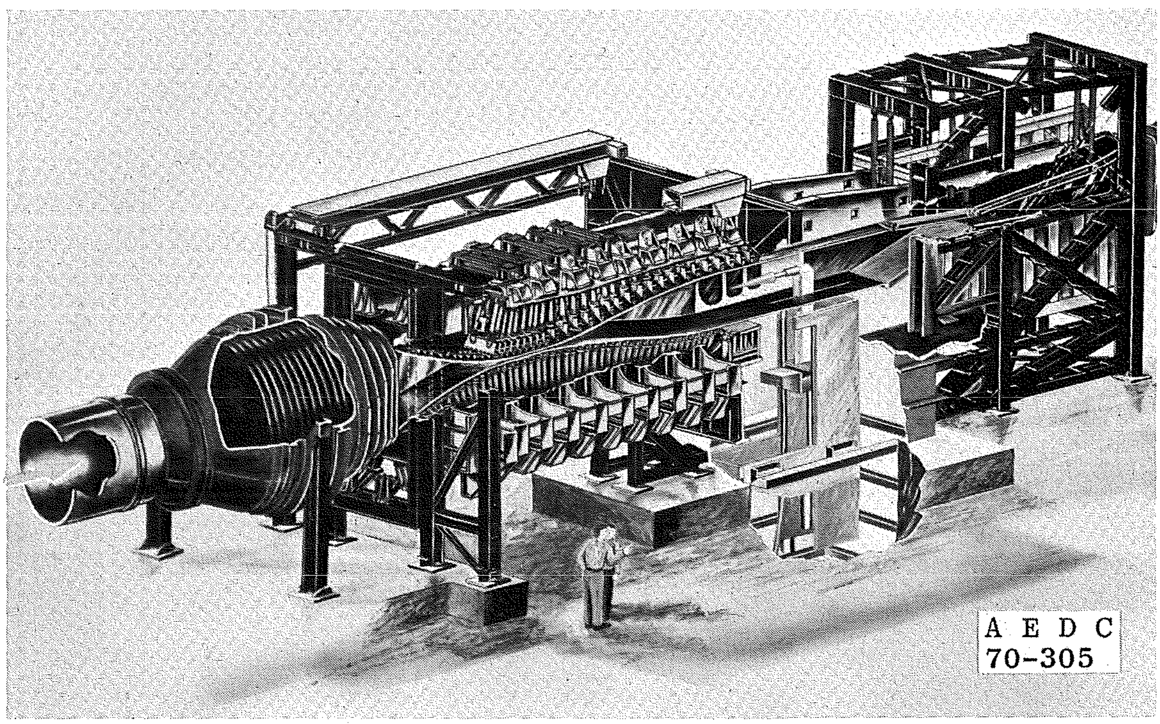
4. DeJarnette, Fred R. and Jones, Michael H. "Calculation of Inviscid Surface Streamlines and Heat Transfer on Shuttle Type Configurations, Part 2 - Description of Computer Program." NASA CR-111922, August 1971.

APPENDIX I

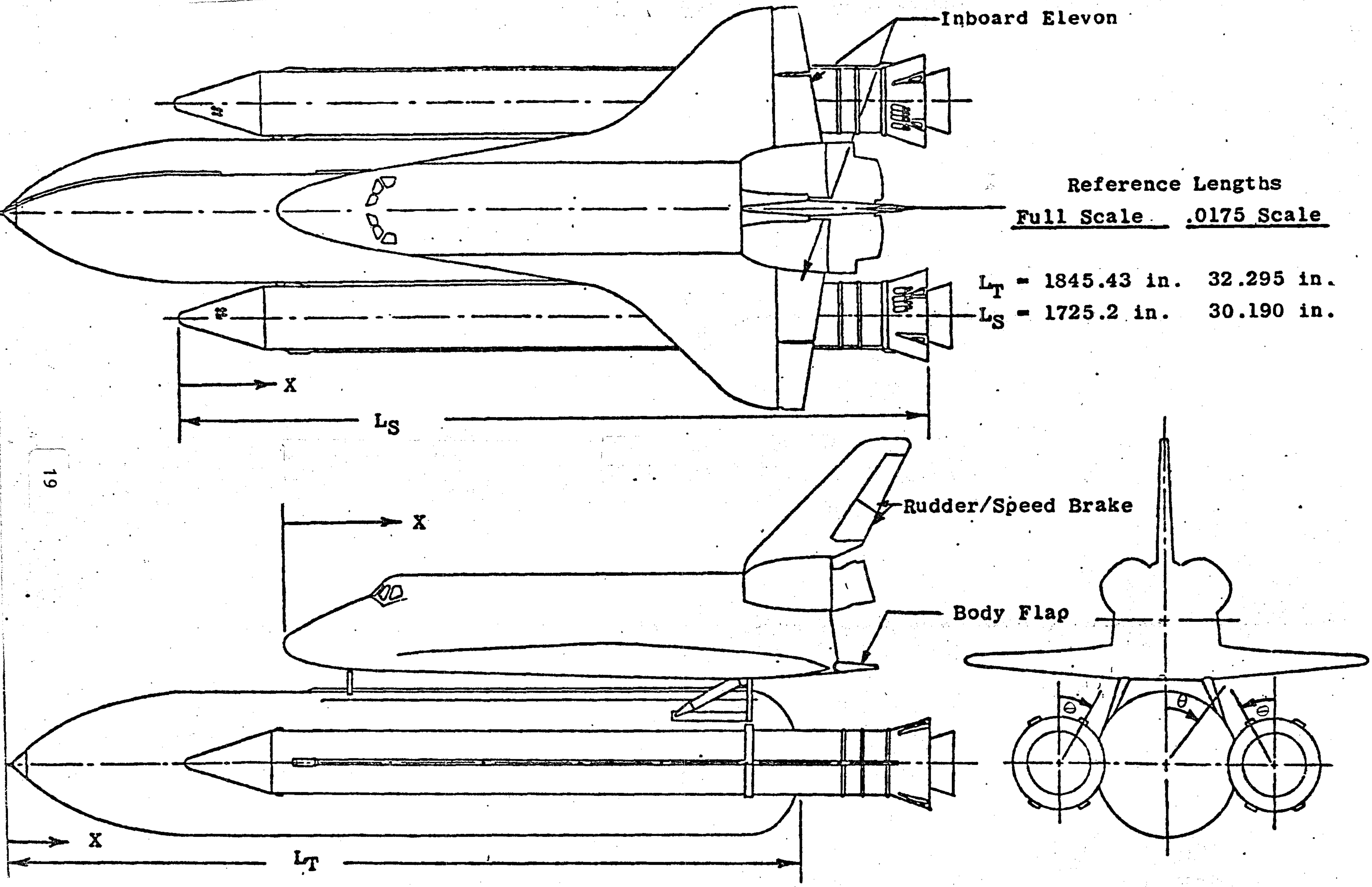
ILLUSTRATIONS



a. Tunnel assembly

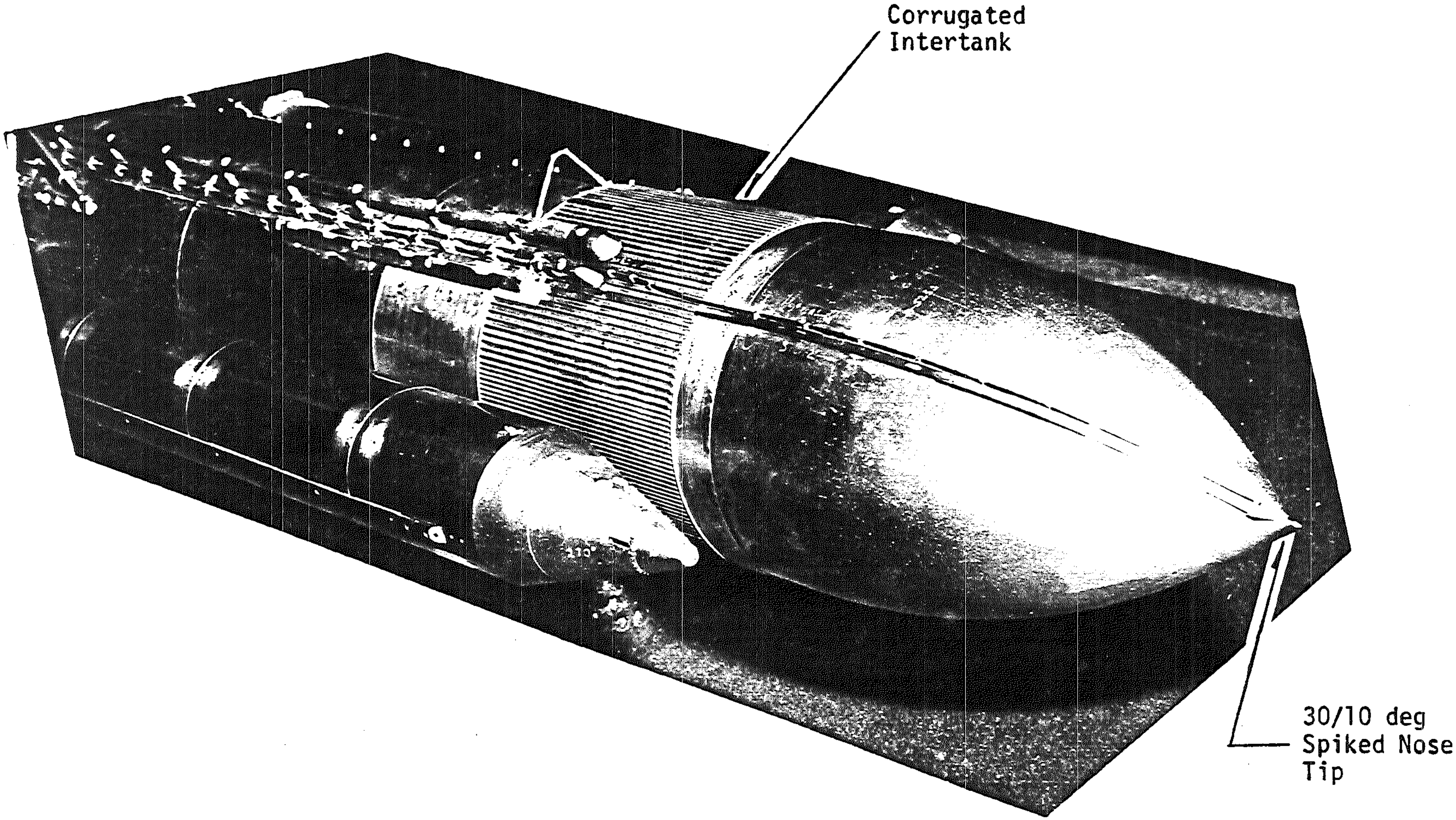


b. Tunnel test section
Fig. 1 Tunnel A

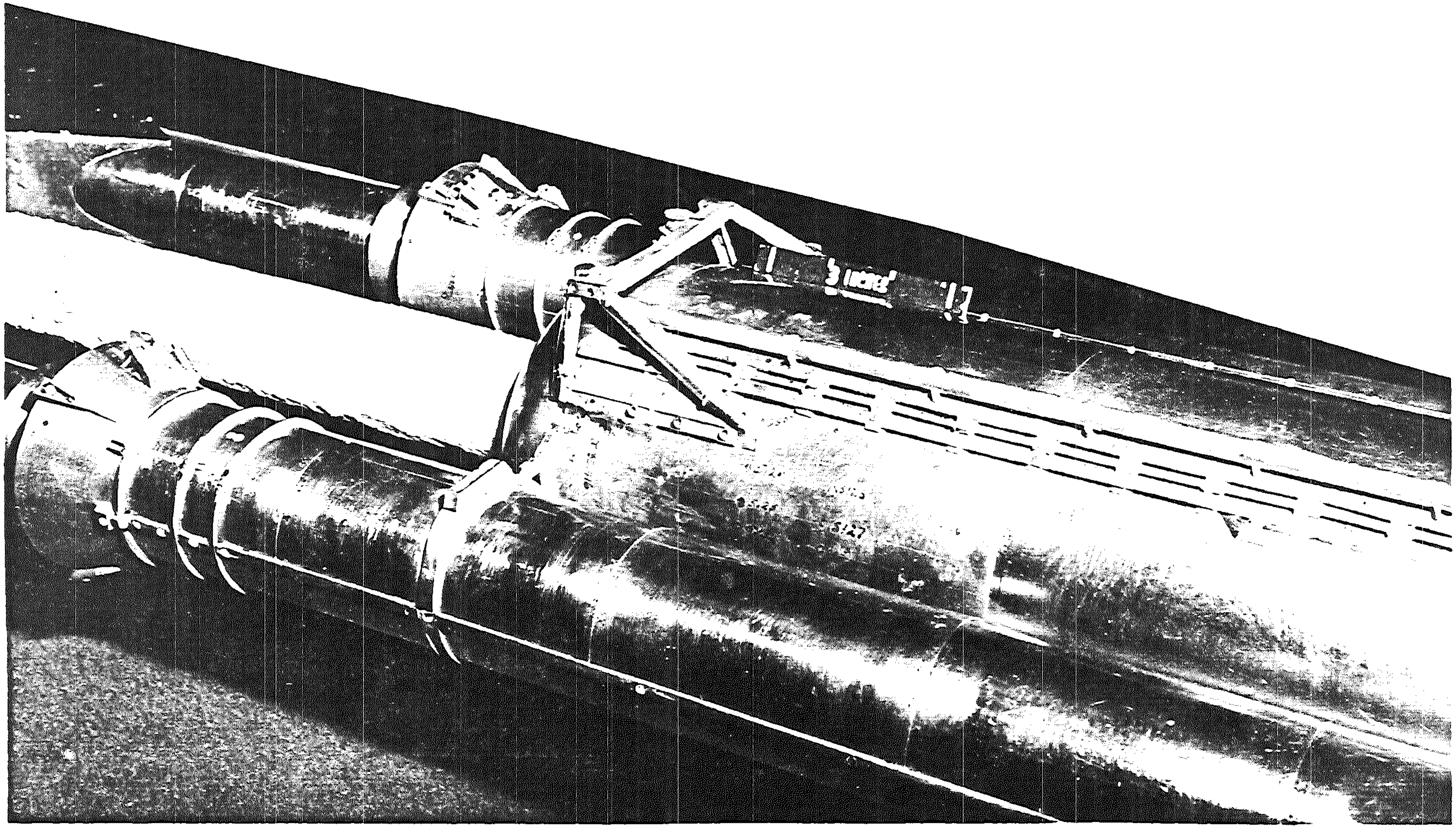


a. Integrated Vehicle - Configuration

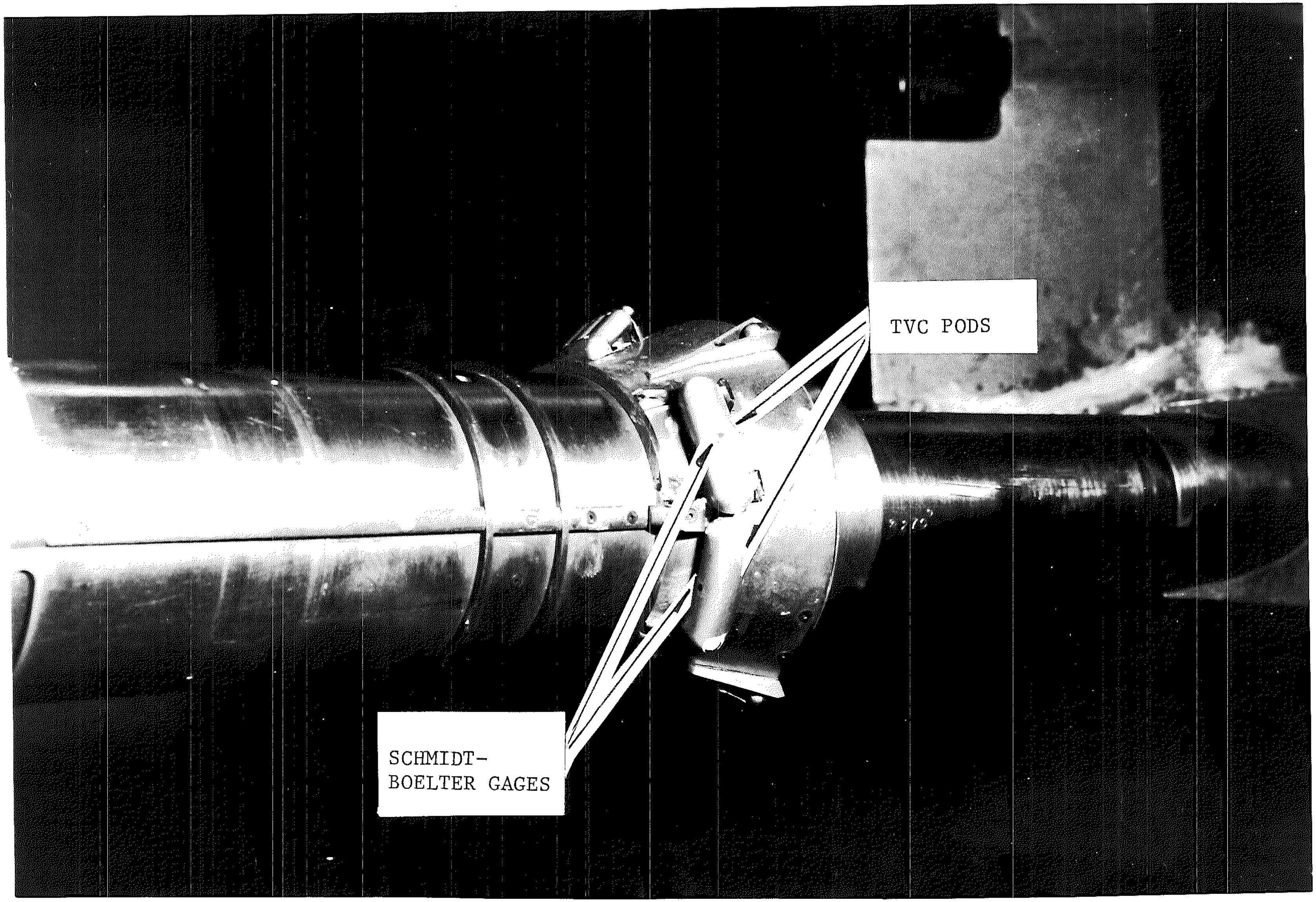
Figure 2. The 60-OTS Integrated Space Shuttle Vehicle



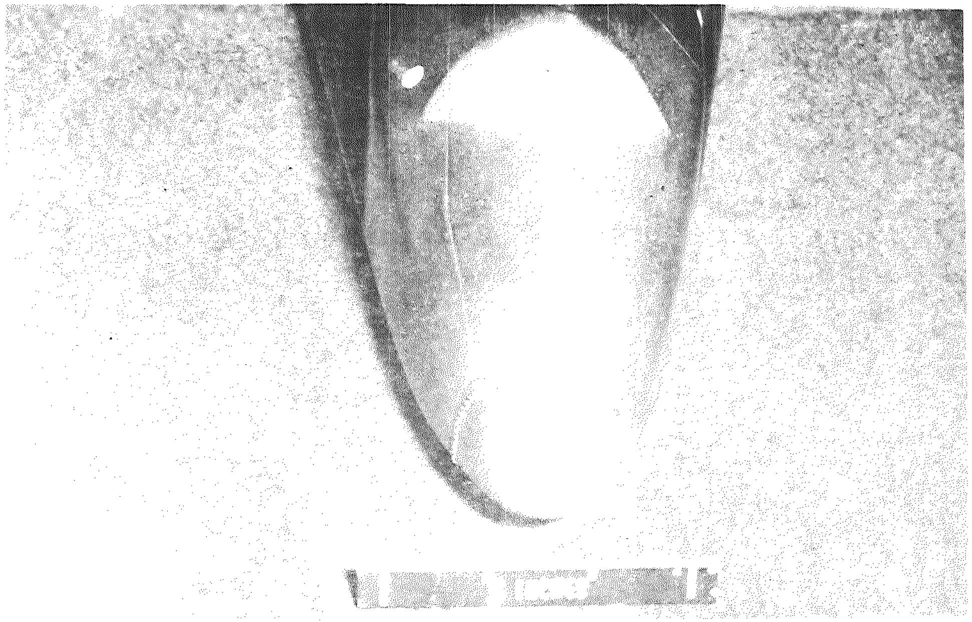
c. Aft Features - External Tank and SRB's
Figure 2. Continued.



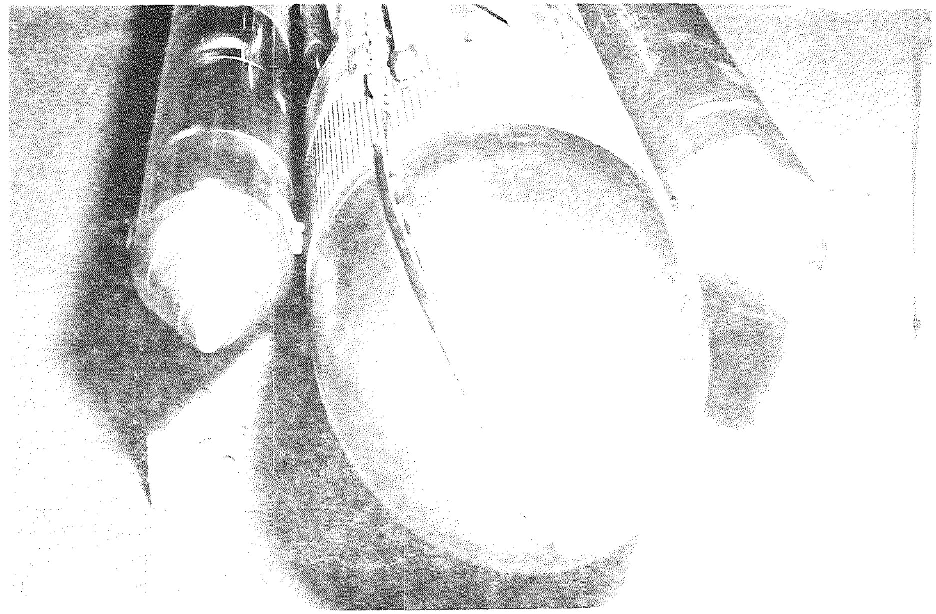
c. Aft Features - External Tank and SRB's
Figure 2. Continued



d. TVC Pods (Left SRB Only)
Figure 2. Continued

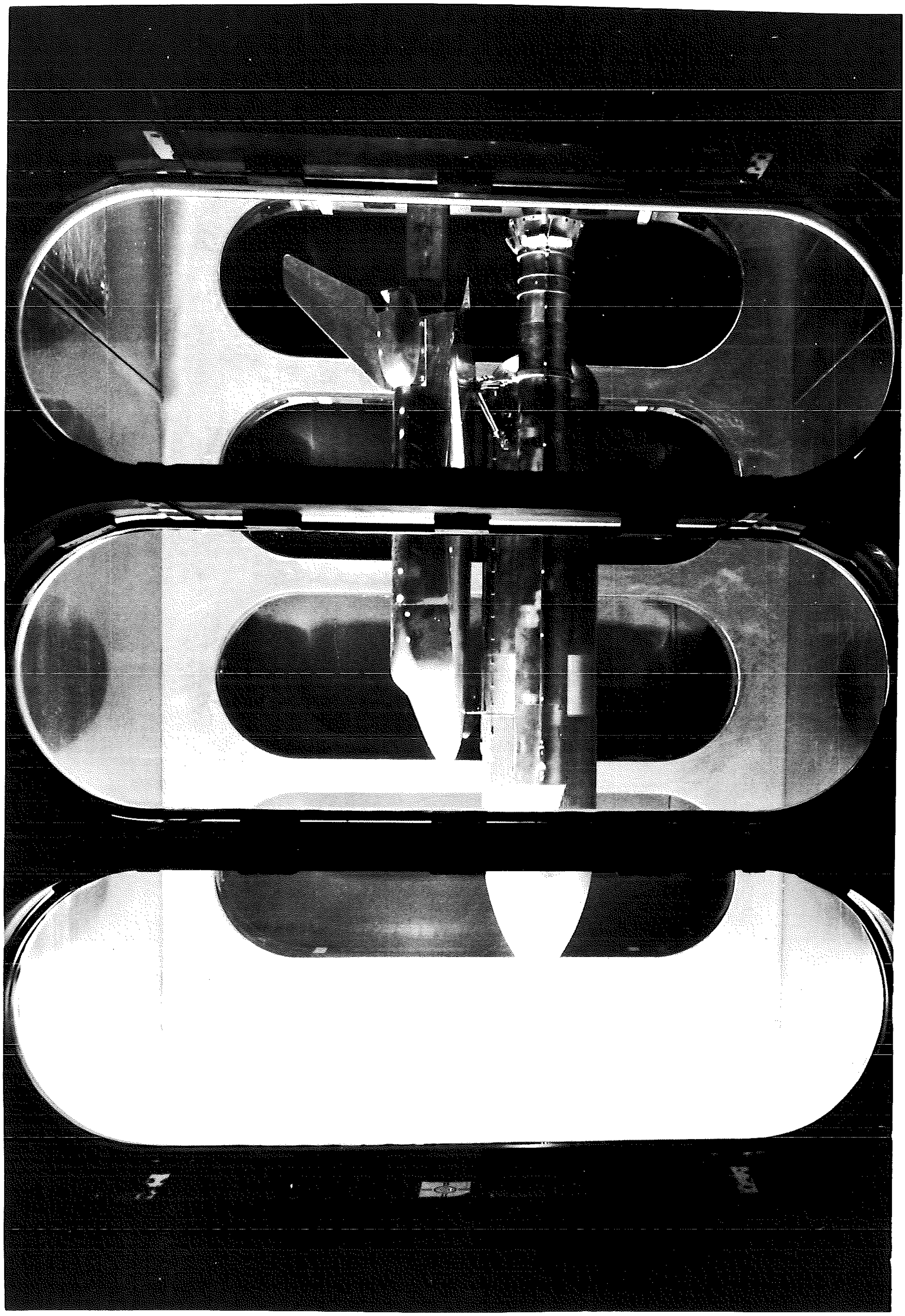


ORBITER
X/L = 0.040



SOLID ROCKET BOOSTERS
S/L = 0.033

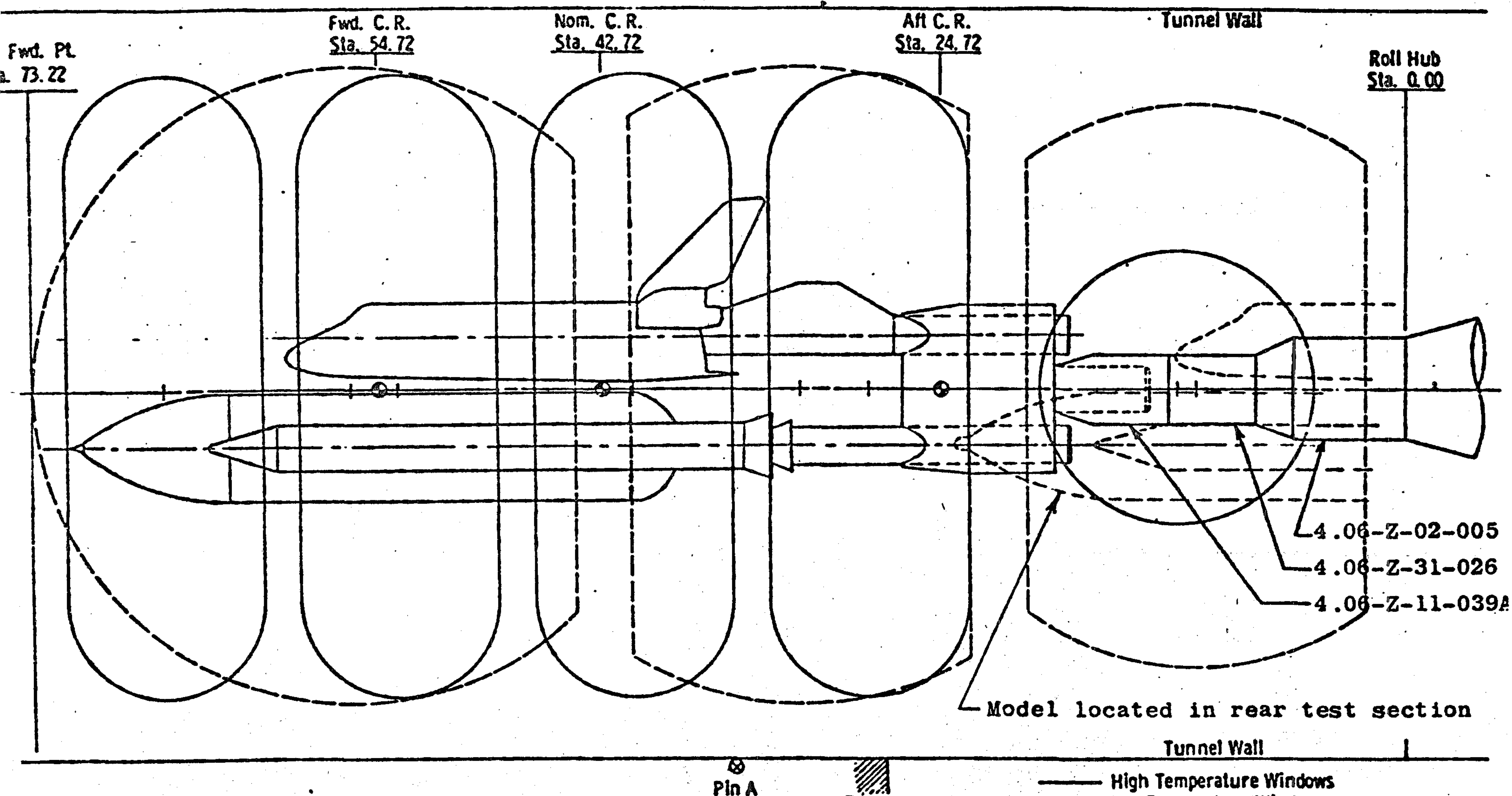
e. Transition Strip Location
Figure 2. Concluded



a. Installation Photograph
Figure 3. Model Installation in Tunnel A

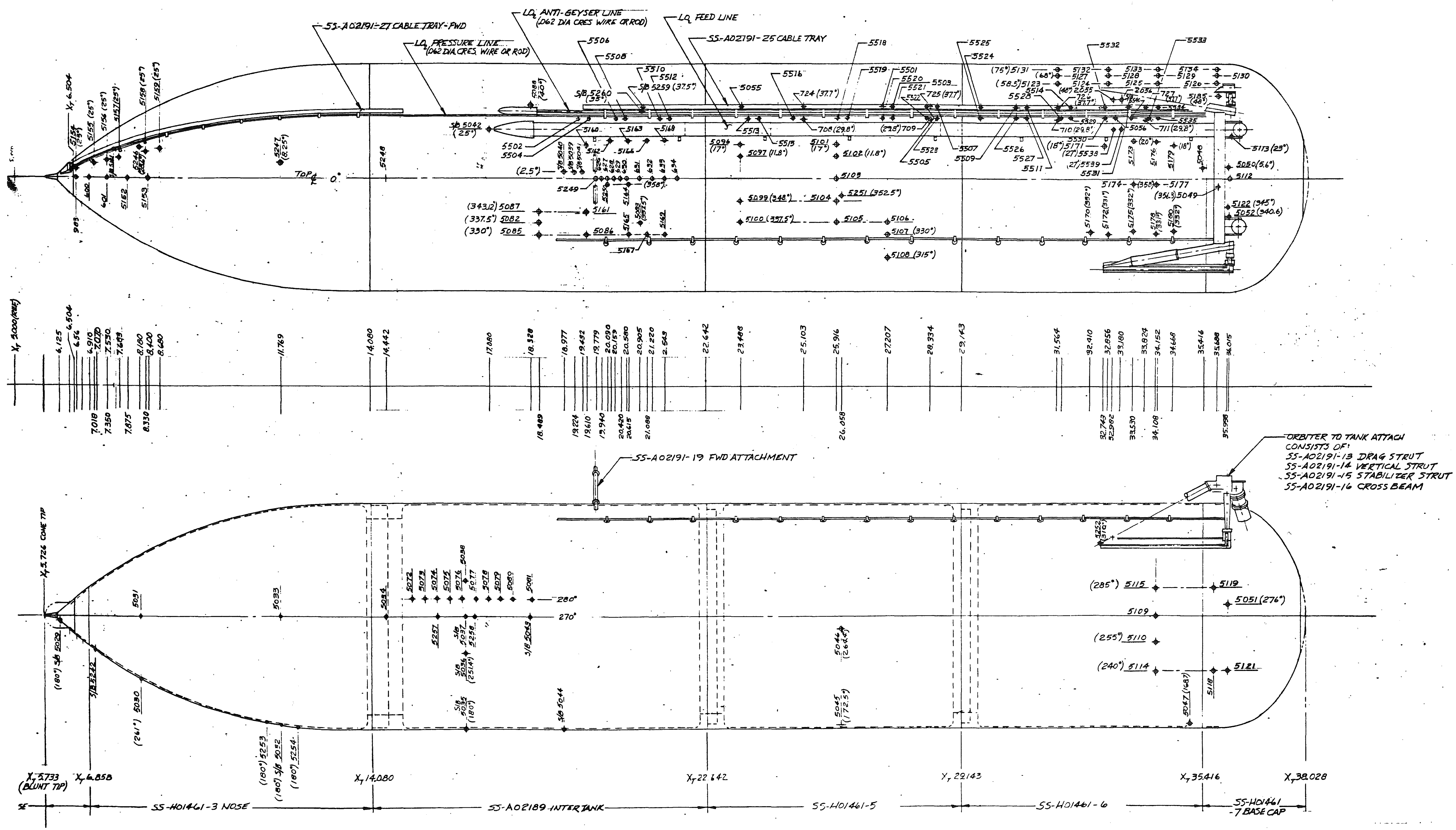
40-INCH SUPERSONIC TUNNEL A

Scale - 1/5



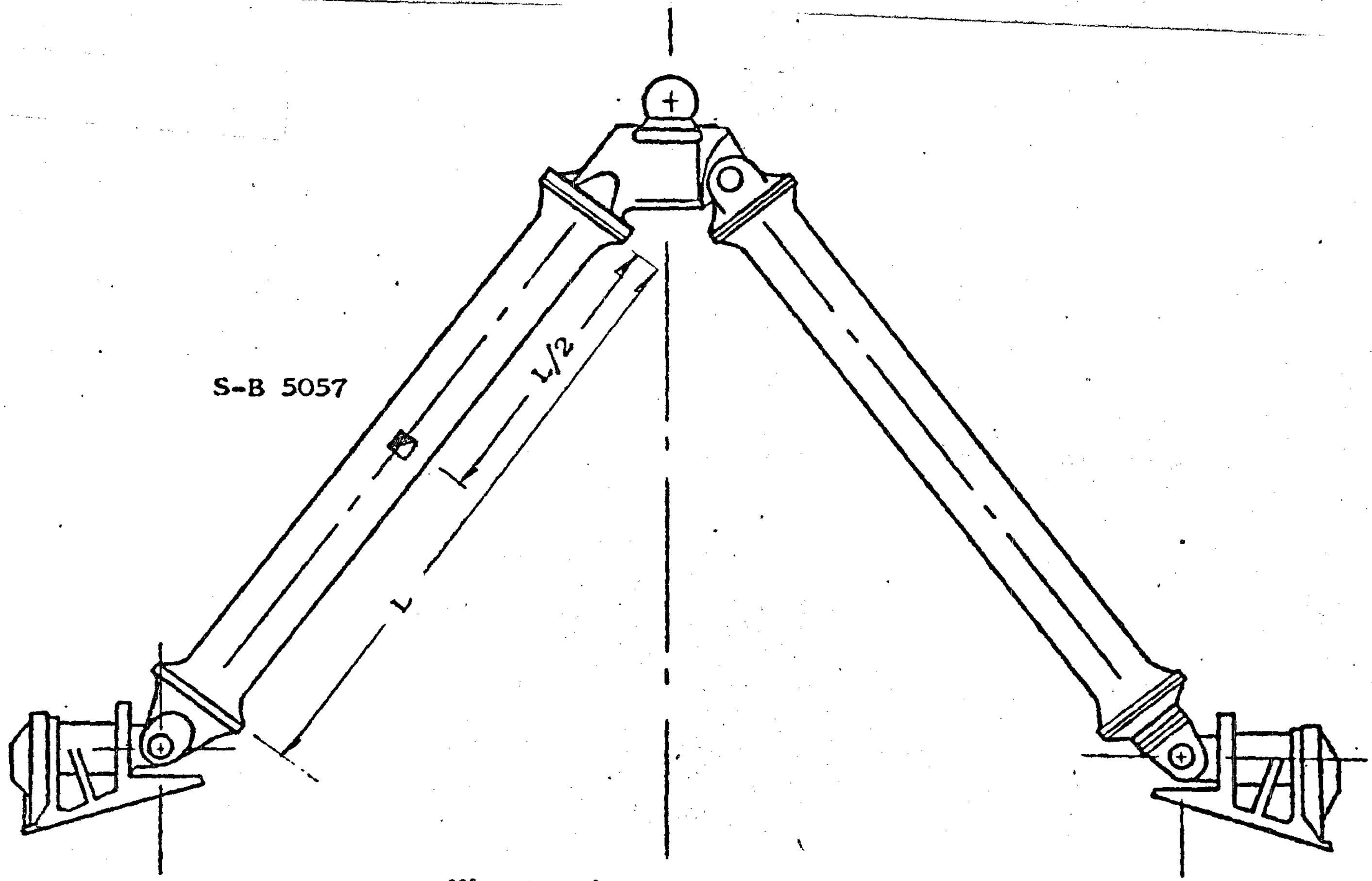
b. Installation Sketch

Figure 3 Concluded



a. Composite

Figure 4. External Tank Instrumentation



View Looking Foward at X 19.773

Figure 4b. Foward Orbiter/ET Attach Structure Instrumentation Location

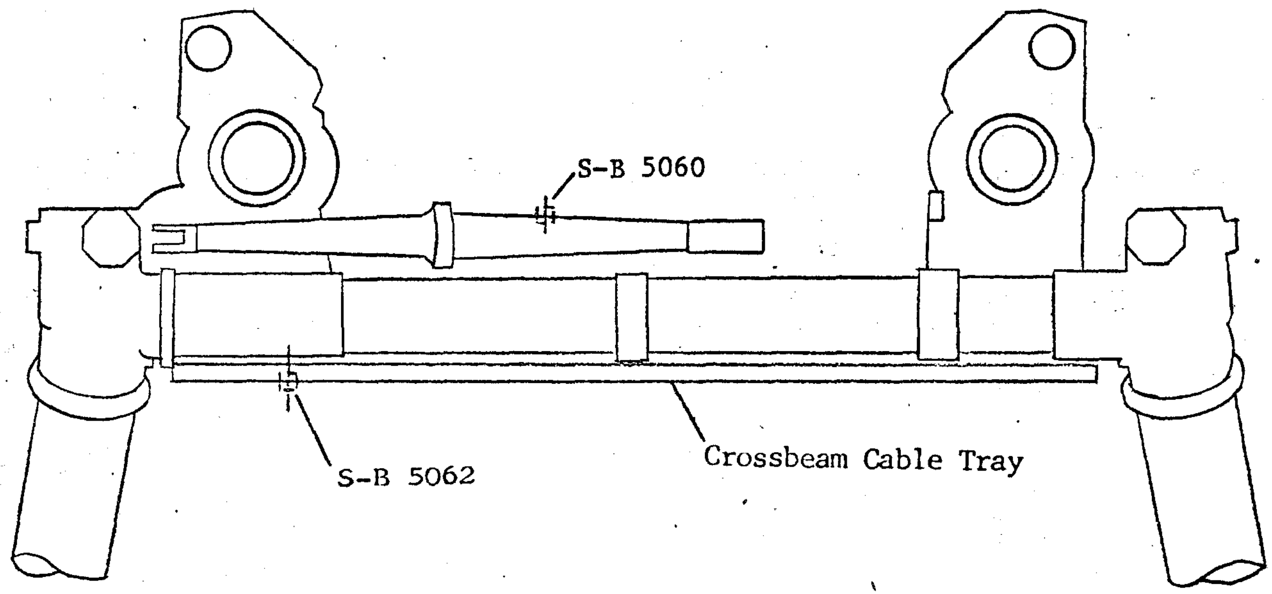


Figure 4c. Aft Orb/ET Attach Structure Instrumentation Location
Crossbeam Cable Tray Detail

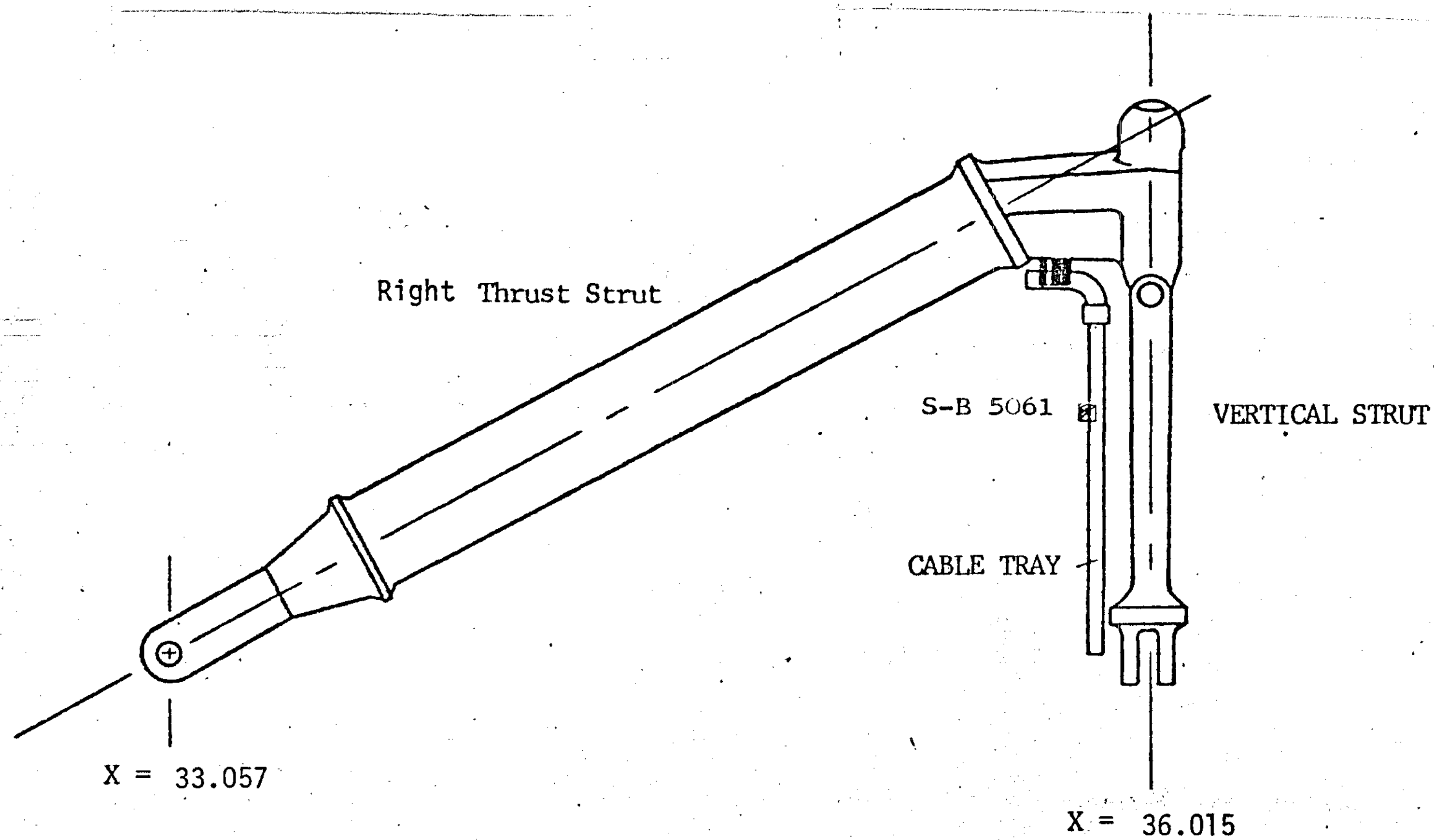


Figure 4d. Aft Orb/ET Attach Structure Instrumentation Location
Vertical Strut Cable Tray Detail

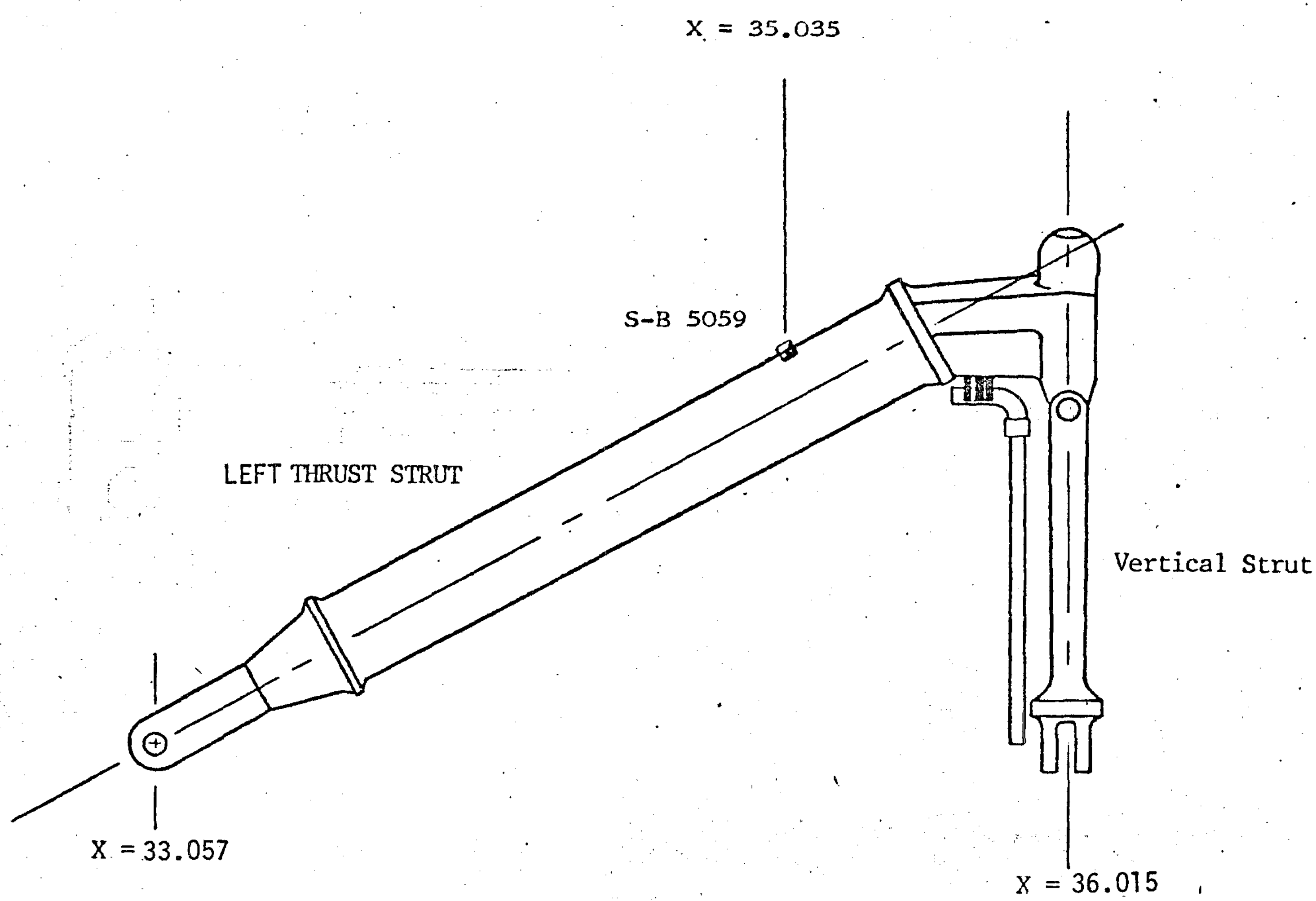


Figure 4e. Aft Orb/ET Attach Structure Instrumentation Location
Thrust Strut Detail

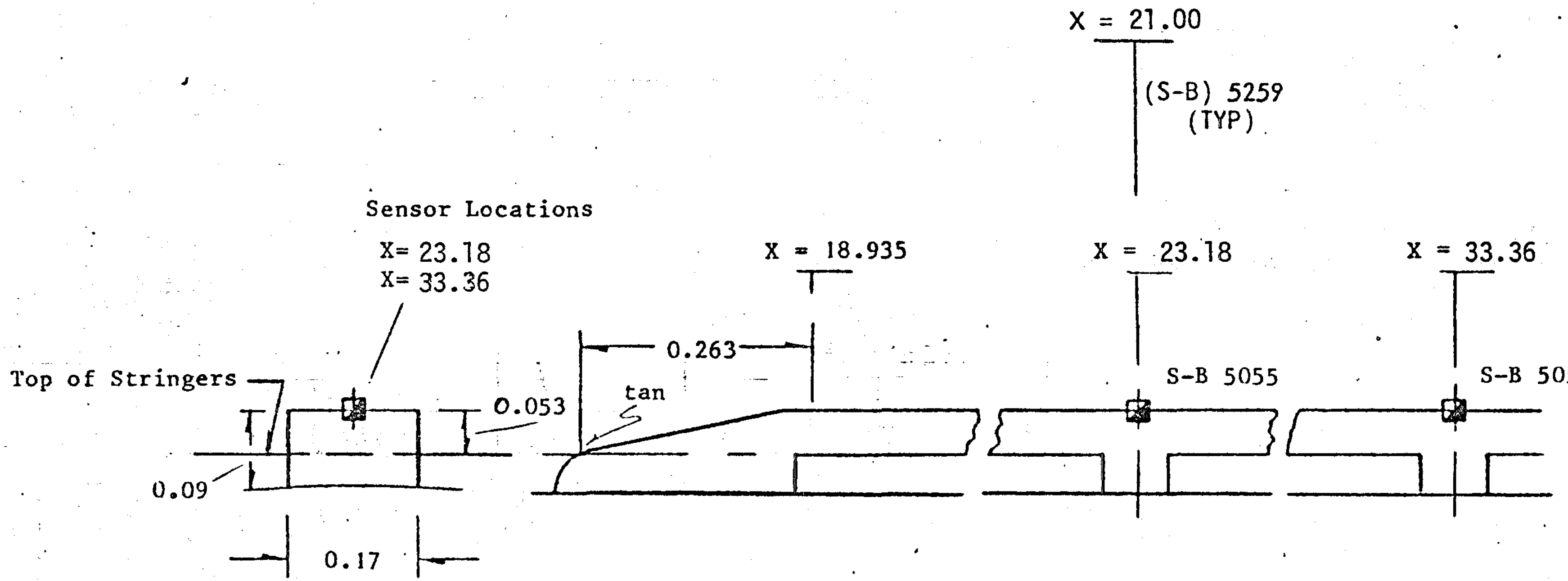
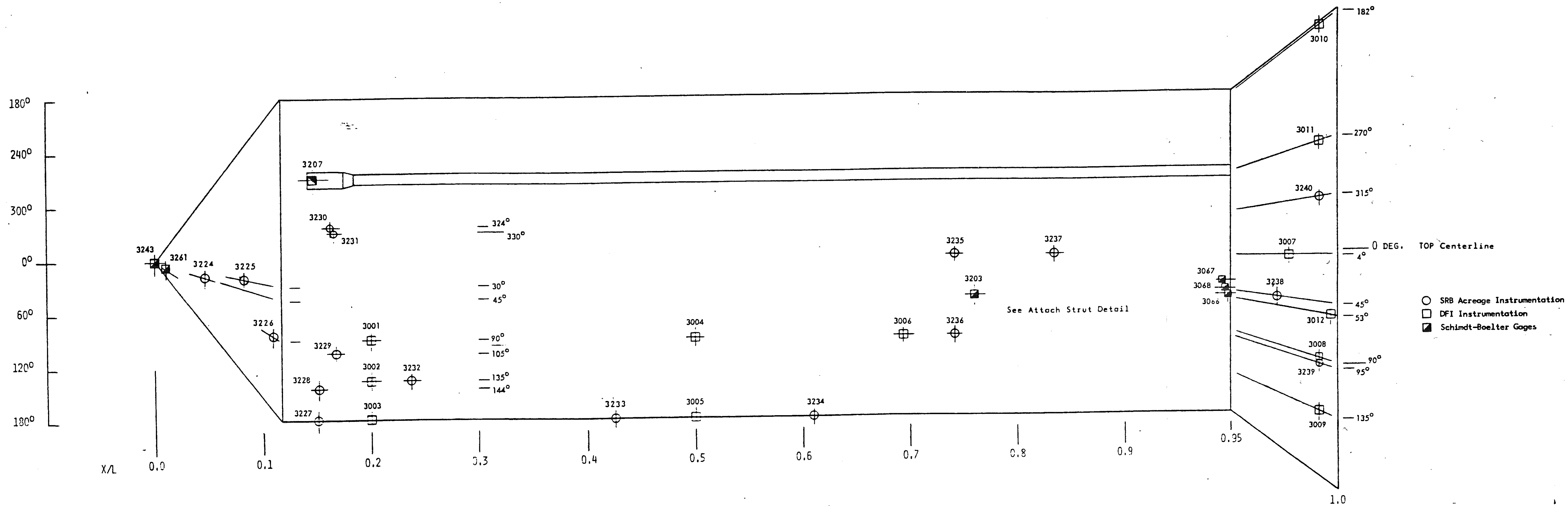
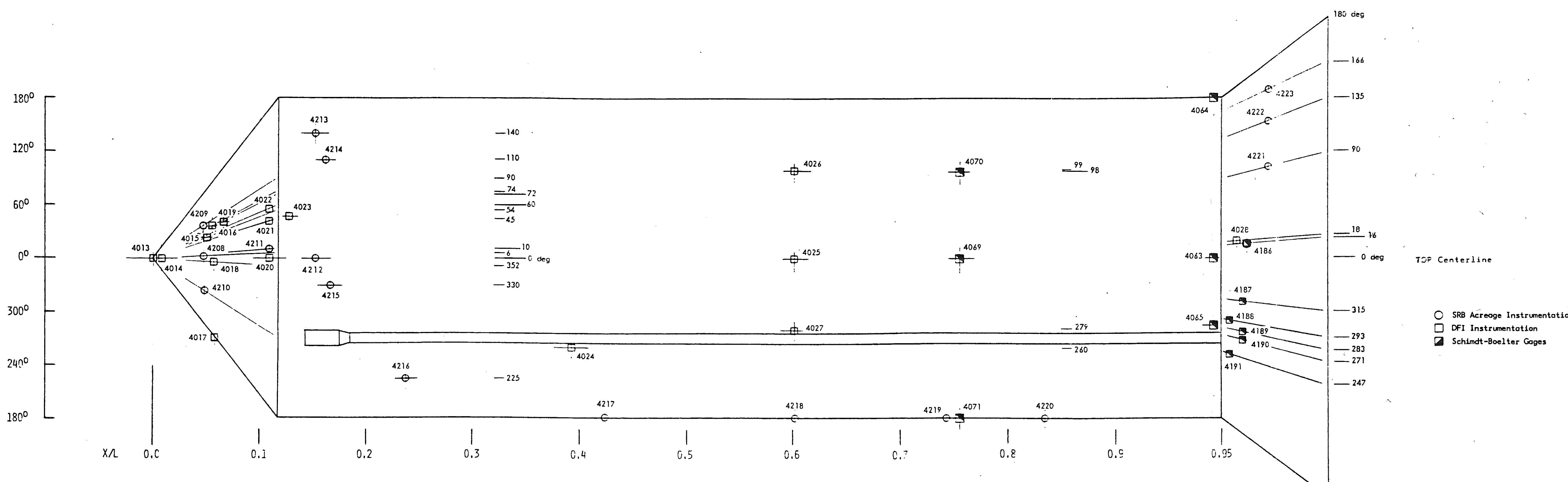


Figure 4f. External Tank Protuberance Instrumentation
LH_2 Cable Tray Detail



a. View of Right Hand SRB's Outer Surface (unrolled and split at the bottom ℄)

Figure 5. SRB Instrumentation



b. View of Left Hand SRB's Outer Surface
(unrolled and split at the bottom ℄)

Figure 5. Continued

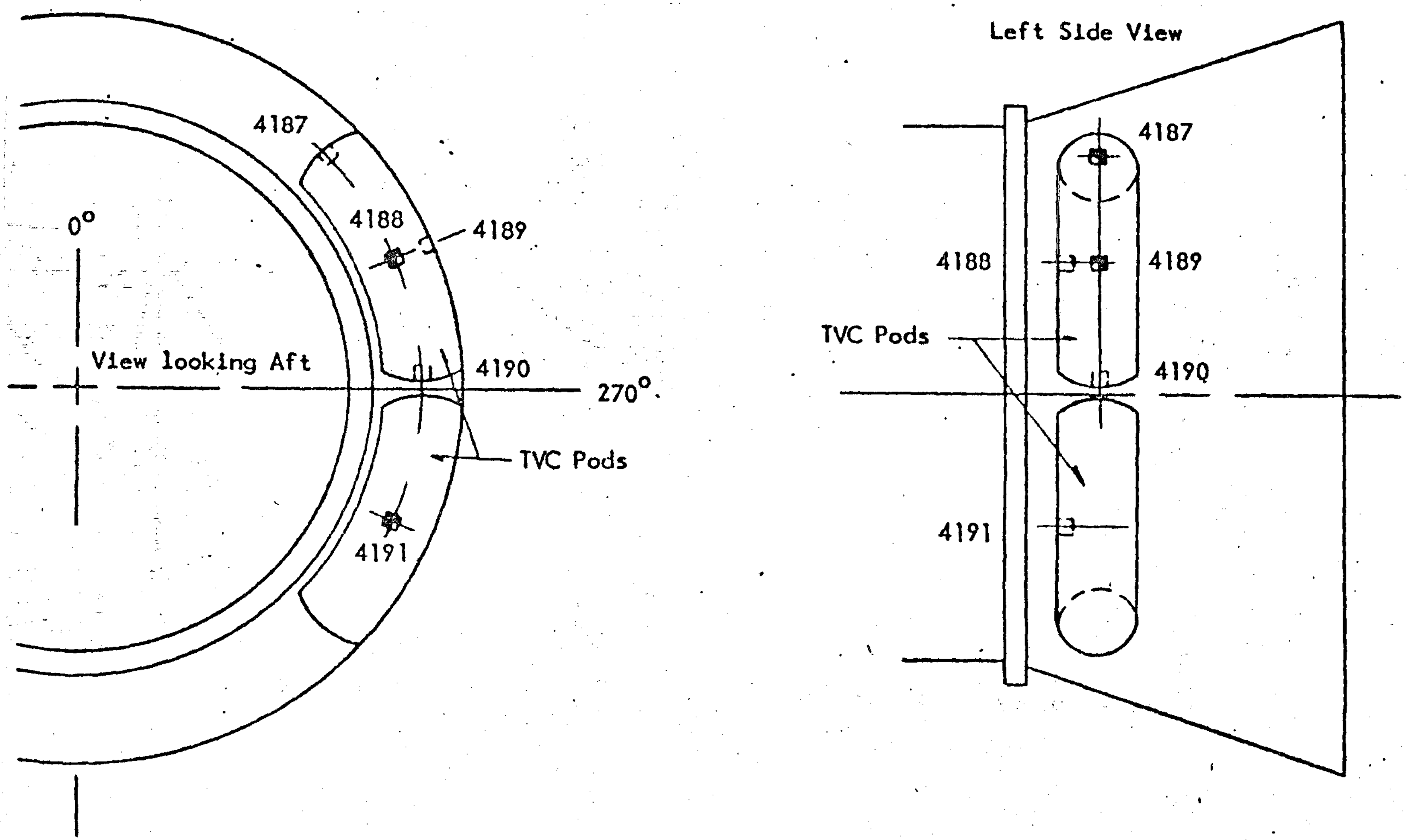


Figure 5c . Left-Hand SRB Instrumentation Location
Thrust Vector Control (TVC) Pod Detail

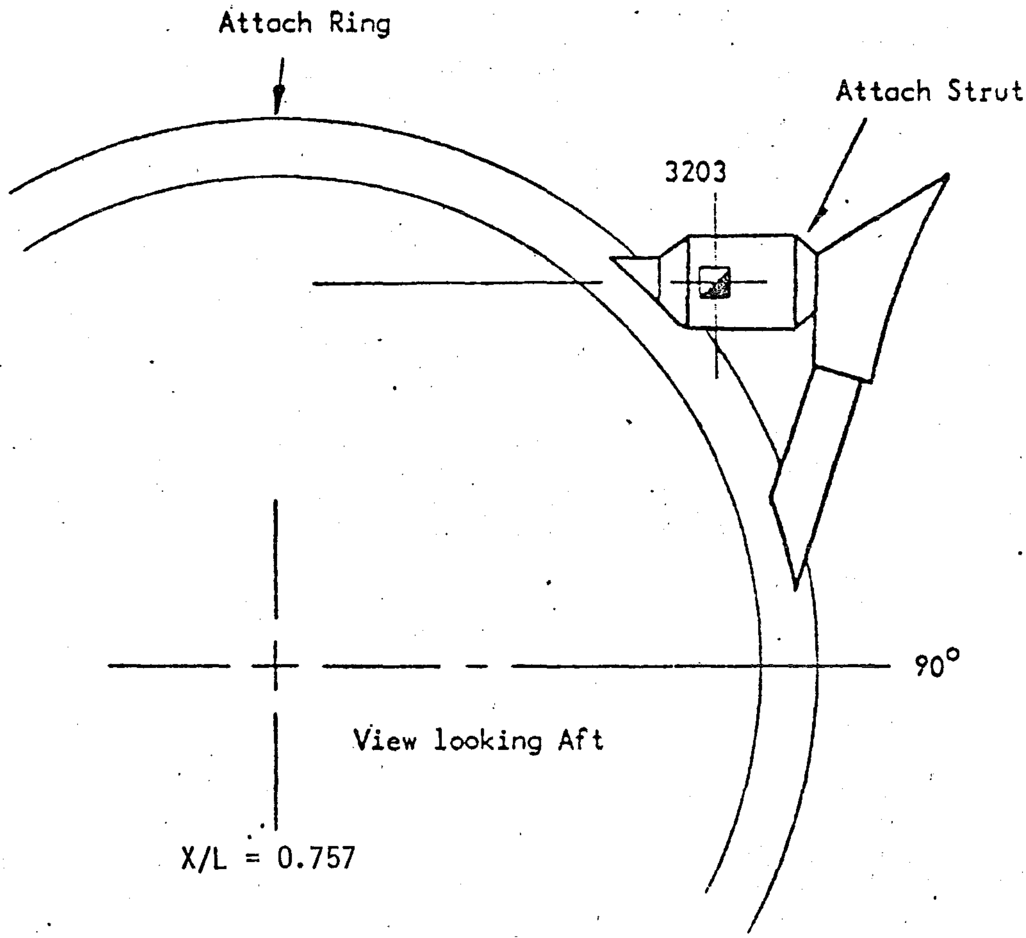


Figure 5d. Right-Hand SRB Instrumentation Location
SRB/ET Aft Attach Strut Detail

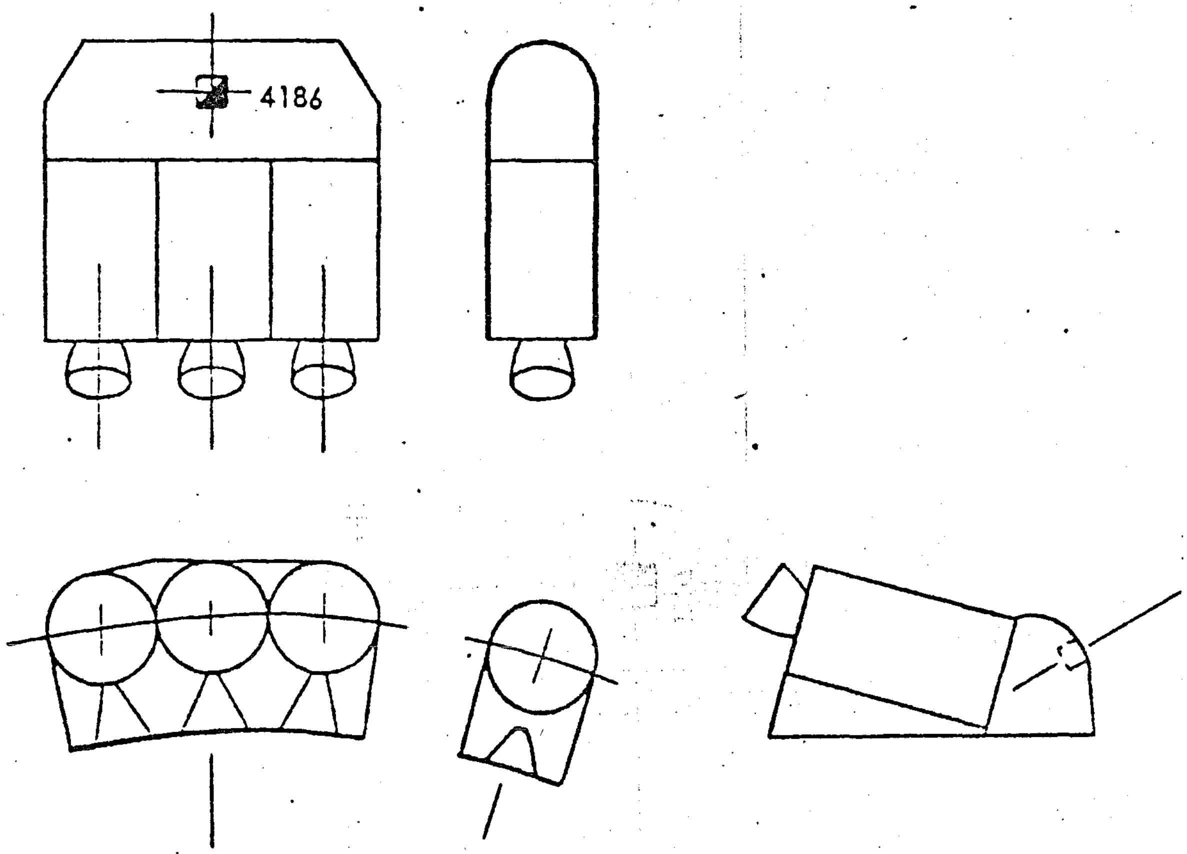


Figure 5e. Left-Hand SRB Instrumentation Location
Aft Separation Motor Detail

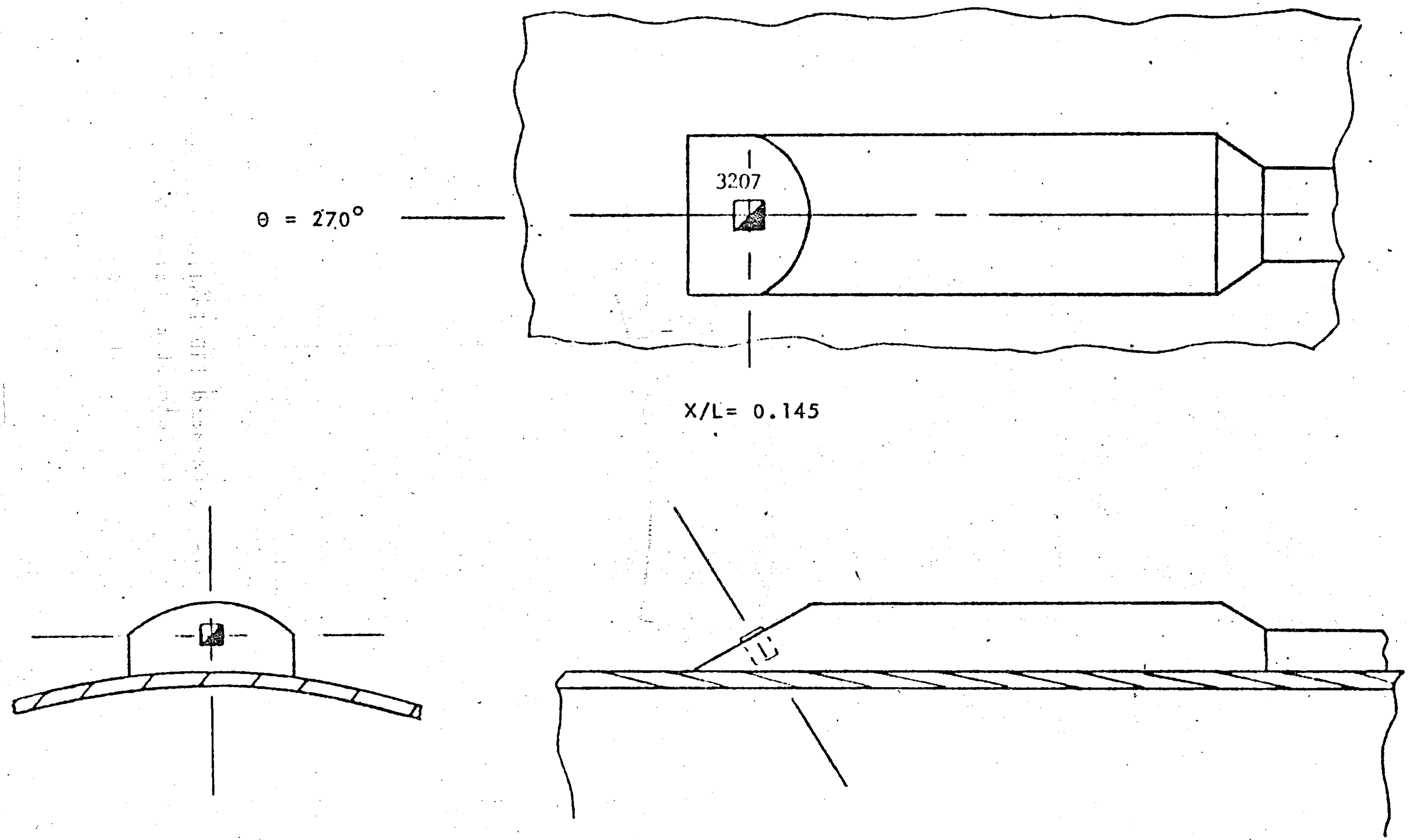


Figure 5f. Right-Hand SRB Instrumentation Location Cable Tray Fairing Detail

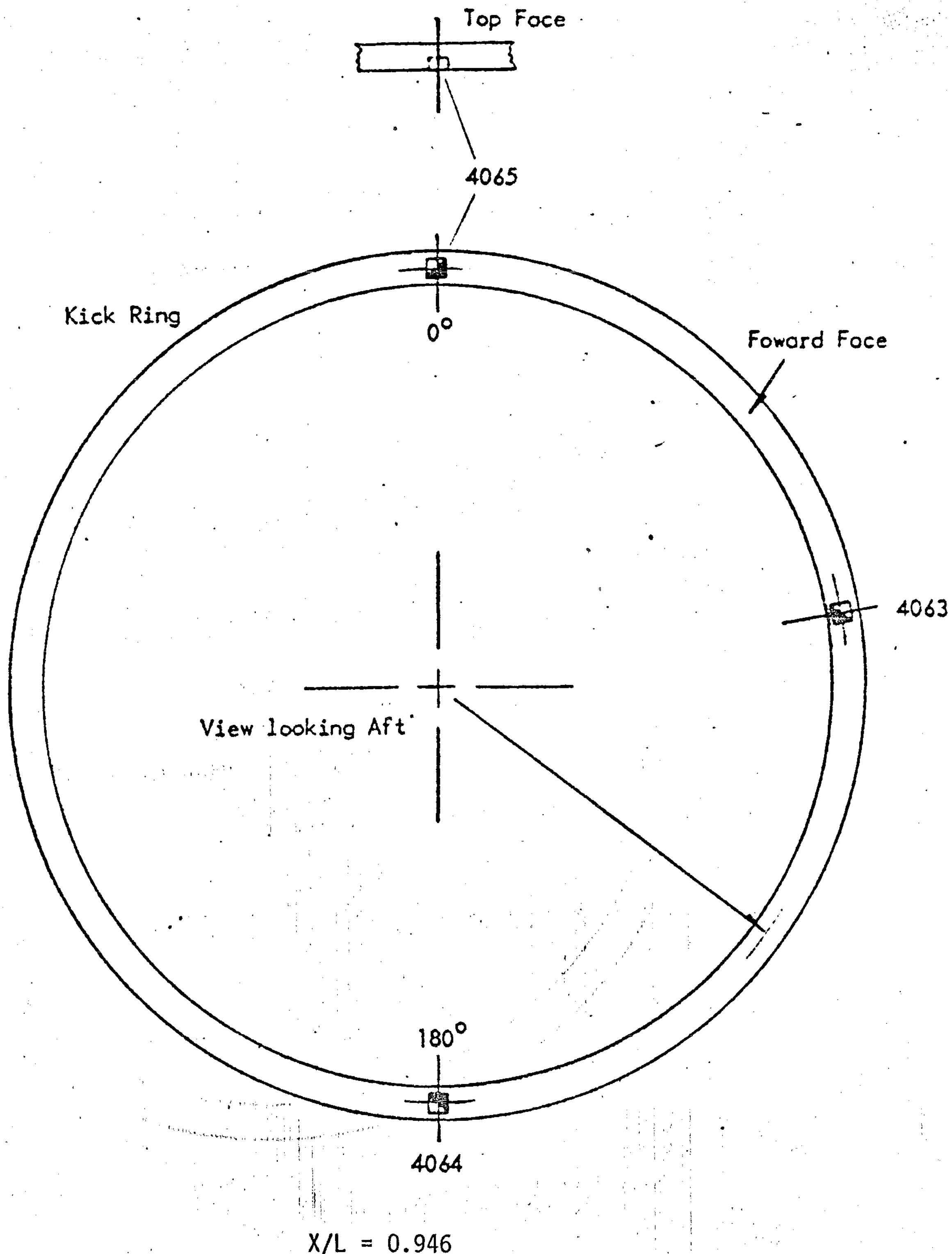


Figure 5g. Left-Hand SRB Instrumentation Location
Kick Ring Detail

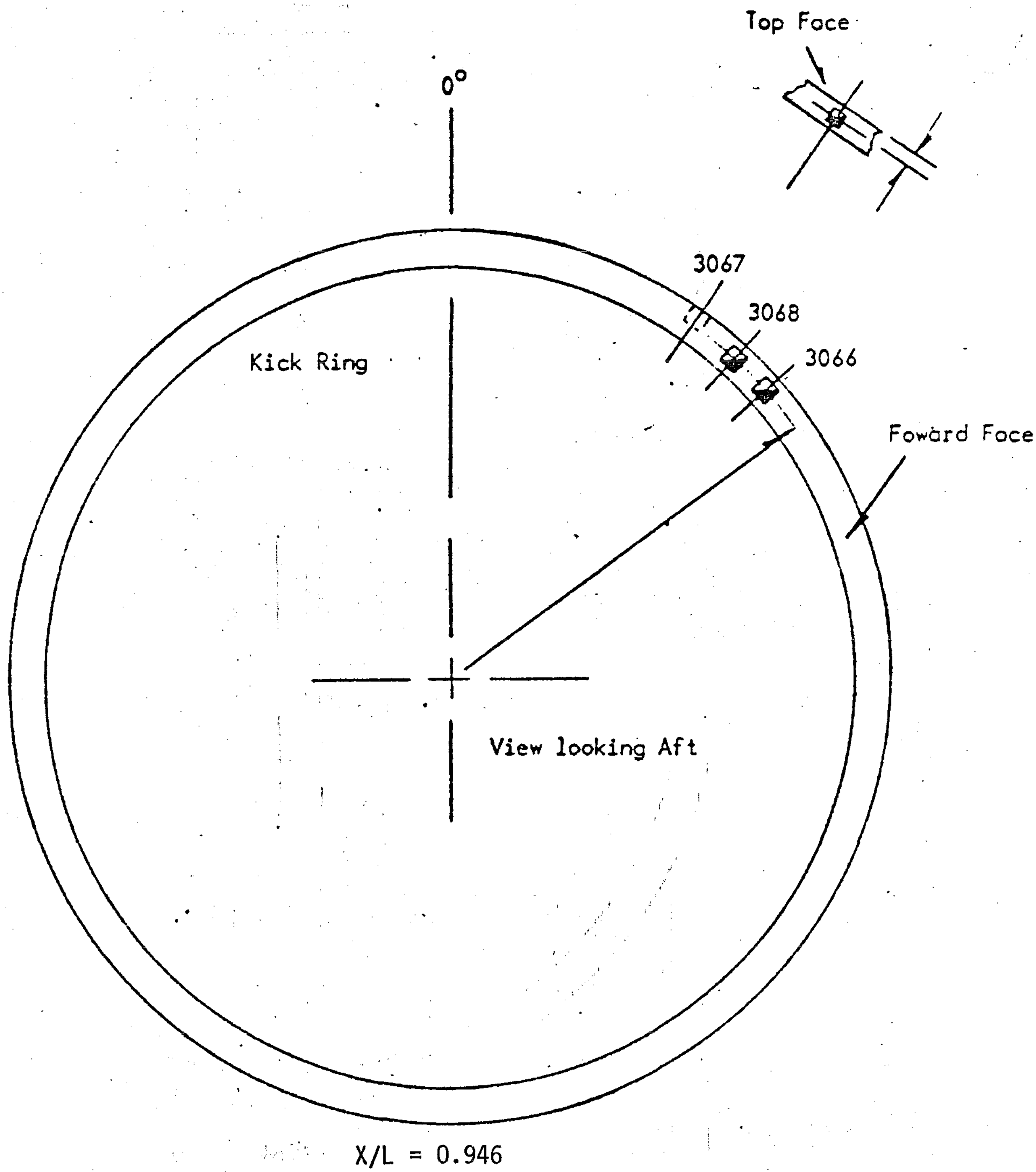


Figure 5h. Right-Hand SRB Instrumentation Location
Kick Ring Detail

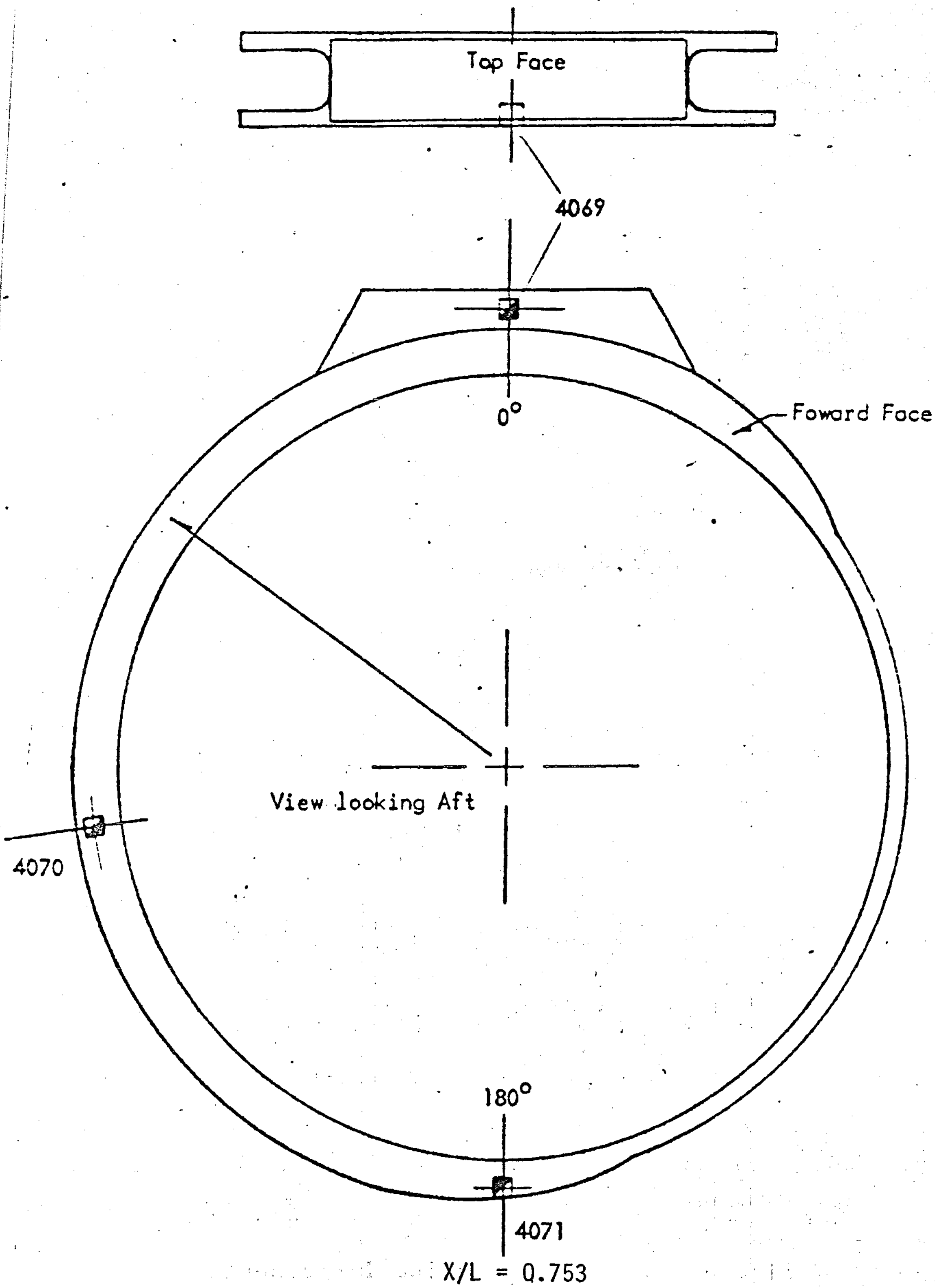


Figure 5j. Left-Hand SRB instrumentation Location
Attach Ring Detail

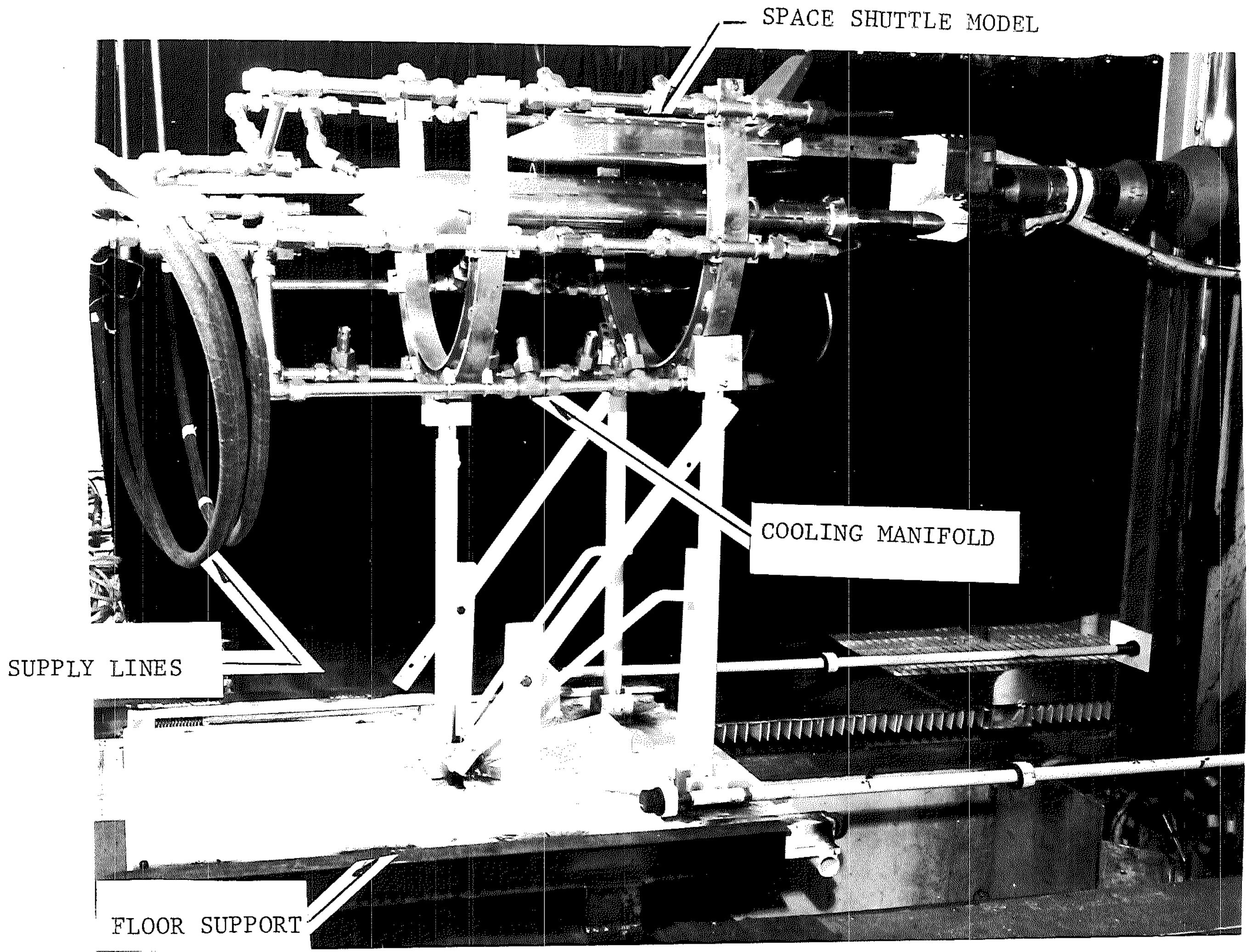


Figure 6. Tunnel A Model Cooling Apparatus

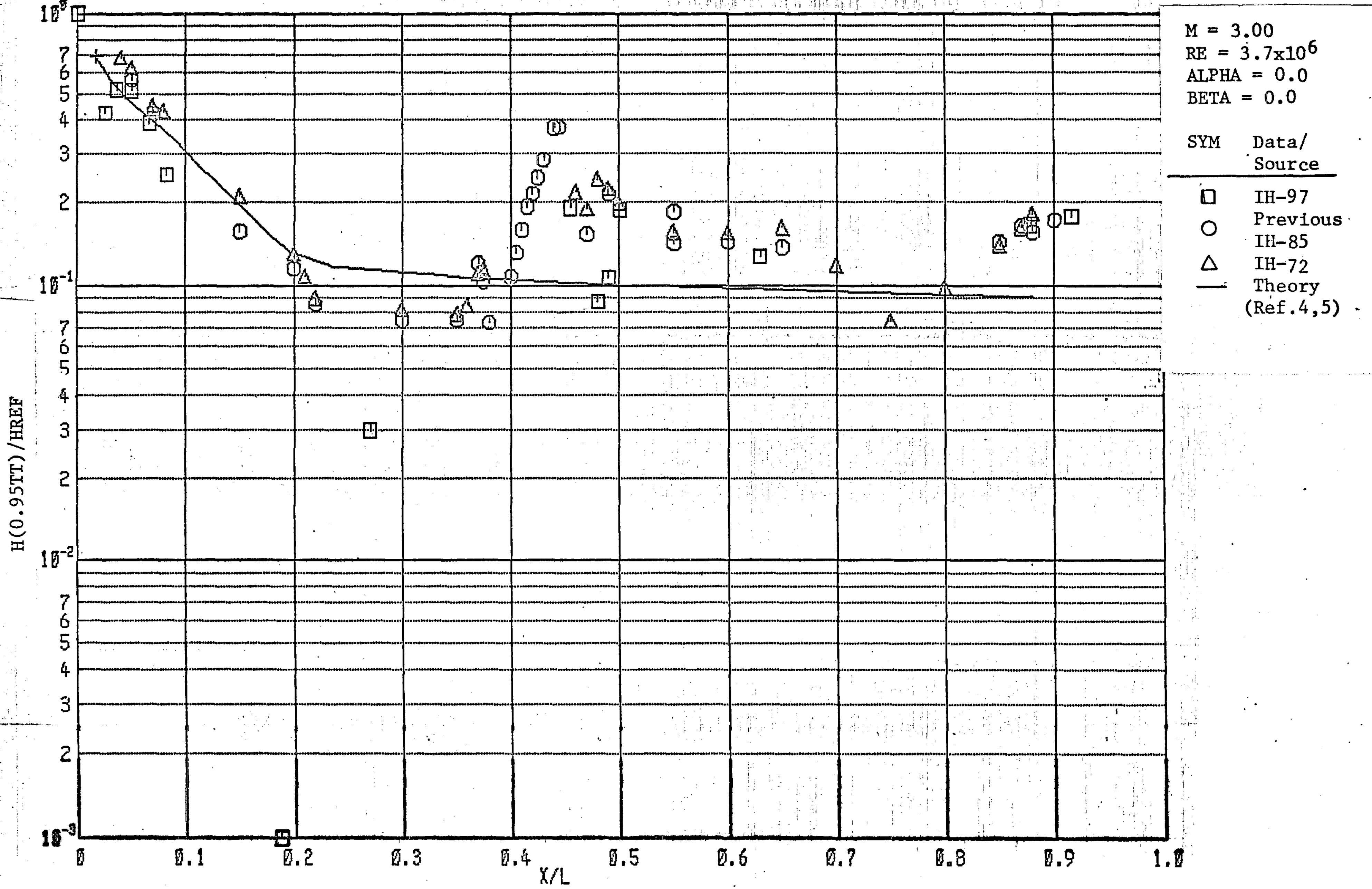


Figure 7. Comparison of External Tank Heating Data from IH-97, IH-85, IH-72 and Theory at M = 3.00

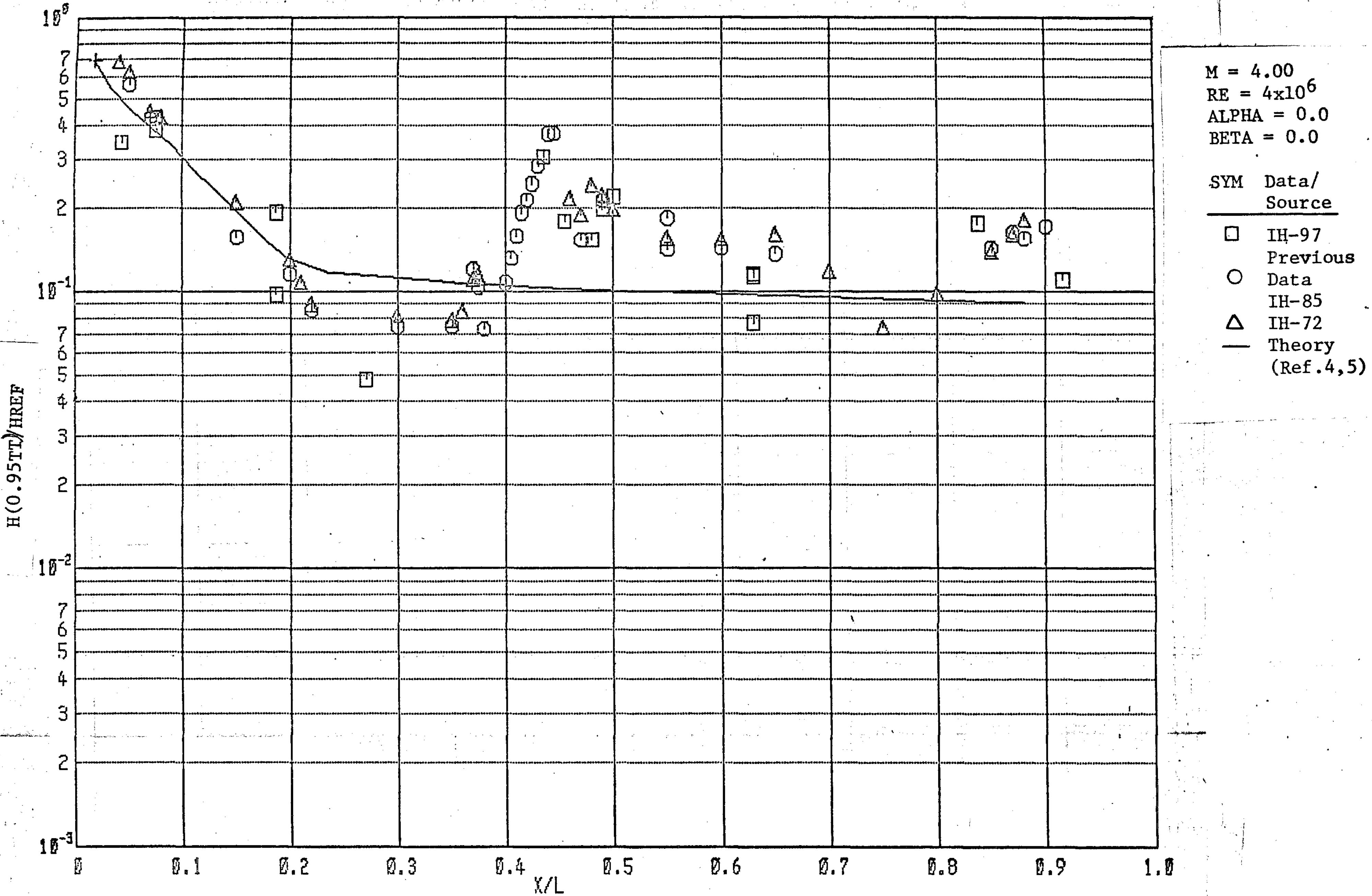


Figure 8. Comparison of External Tank Heating Data from IH-97, IH-85, IH-72 and Theory at M = 4.00

APPENDIX II

TABLES

TABLE 1. Data Transmittal Summary

The following items were transmitted to the following:

	Mrs. D. B. Lee NASA/JSC E33 Houston, TX 77058	Mr. Paul Lemoine Rockwell International Space Division 12214 Lakewood Blvd. Downey, CA 90241	Mr. E. C. Knox Rockwell International Space Division 3322 S. Memorial Pkwy. Huntsville, AL	Mr. L. D. Foster NASA/MSFC Huntsville, AL 35218
Item	No. of Copies	No. of Copies	No. of Copies	No. of Copies
Test Summary Report	1	4	1	3
Data Package	1	3	1	3
Final Data Tape		1		1
Installation Photos	1	1	1	1
Model Photographs	1	1	1	1
70 mm shadowgraph and Schlieren Stills				
Contact Prints		1		1
Duplicate Negative		1		

PROJECT NUMBER C767VA TESTING COMPLETED 10/19/82 TABLE COMPLETED 11/30/82	MEASUREMENT UNCERTAINTY TABLE 2	DATA QUALITY CERTIFIED: ORIGINATOR W. K. Crain DATE 11/30/82 CHECKED BY K. W. Nutt DATE 11/31/82

Parameter Designation	ESTIMATED MEASUREMENT* Precision Index ±(S) Percent of Reading	Precision Index ±(S) Unit of Measurement	Degree of Freedom	+ Bias ±(B) Percent of Reading	+ Bias ±(B) Unit of Measurement	Uncertainty $\pm(B + t_{95}S)$ Percent of Reading	Uncertainty $\pm(B + t_{95}S)$ Unit of Measurement	Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
PT, psia		0.007 0.017	>30 >30	0.2% 0.2%		±(0.2% + 0.014) ±(0.2% + 0.034)		60 150	Bell & Howell Force Balance Pressure Transducer	Digital Data acquisition system analog-to-digital converter	In-place application of multiple pressure levels measured with pressure measuring device calibrated in the standards laboratory
TT, °F		1	>30		2		4	0–300	Chromel®-Alumel® Thermocouple	Doric temperature instrument digital multiplexer	Thermocouple verification of NBS conformity/ voltage substitution calibration
TW, °F (Thin skin only)		1	>30		2		4	0–300	Chromel®-Constantan® Thermocouple	Thermoplexer/Multiverter/RADS/DEC 10 System	Voltage substitution calibration, secondary standard
Time Code Generators, sec		5×10^{-4}	>30	Runtime(sec)x5x 10^{-6}		[Runtime(sec)x5x 10^{-6}] + 10^{-3}		ms–365 days	Systron Donner time code generator	Digital data acquisition system	Instrument lab calibration against Bureau of Standards
Sector pitch angle, deg		0.025	>30				0.05	±15	Potentiometer	Digital data acquisition system analog-to-digital converter	Hiedenhain rotary encoder ROD 700 Resolution: 0.0006° Overall accuracy: 0.001°
Sector roll angle, deg		0.015	>30				0.3	±180			

*REFERENCE: Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5, February 1973
NOTES:

GC-35 (Combines GC-35 & GC-120) 1/82 Previous editions will be used

TABLE . Concluded

b. Calculated Parameters

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT*							Range
	Precision Index $\pm(S)$			Bias $\pm(B)$		Uncertainty $\pm(B + t_{95}S)$		
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	
M		0.008			0+		0.016	All
RE,ft^{-1}		0.50		0.2		1.2		All
H(0.95TT),BTU/ft^2-sec (Thin skin only)						10 11 12		10^{-2} 10^{-3} 10^{-4}

NOTES:

1. Uncertainty for the thin-skin measurements in the External Tank corrugated intertank area is undetermined. Due to the geometry of this area only "effective" skin thicknesses were supplied.

2. Use of the Schmidt-Boelter gages is a relatively new and unproven technique, especially in the small diameter protuberance areas. Consequently uncertainty on the Schmidt-Boelter gage measurements is not quoted.

*Abernethy, R. B. et al. and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.

+ Assumed to be zero

TABLE 3. Phase A Instrumentation and Constants

Gage, TC No.	Skin Thickness (in.)	X/L	θ (deg)	N_X	N_Y	N_Z
3001	0.0295	0.1990	90.0000	0.0000	-1.0000	0.0000
3002	0.0300	0.1990	135.0000	0.0000	-0.7070	-0.7070
3003	0.0300	0.1990	180.0000	0.0000	0.0000	-1.0000
3004	0.0290	0.4980	90.0000	0.0000	-1.0000	0.0000
3005	0.0290	0.4980	180.0000	0.0000	0.0000	-1.0000
3006	0.0290	0.6920	90.0000	0.0000	-1.0000	0.0000
3007	0.0310	0.9740	4.0000	-0.3201	-0.0661	0.9451
3008	0.0315	0.9880	90.0000	-0.3201	-0.9474	0.0000
3009	0.0320	0.9880	135.0000	-0.3201	-0.6699	-0.6699
3010	0.0310	0.9880	182.0000	0.3201	0.0331	-0.9468
3011	0.0300	0.9880	270.0000	-0.3201	0.9470	0.0000
3012	0.0300	0.9940	53.0000	-0.3201	-0.7566	0.5702
4013	0.0285	0.0000	0.0000	-1.0000	0.0000	-1.0000
4014	0.0285	0.0081	0.0000	-0.3090	0.0000	0.9510
4015	0.0290	0.0497	54.0000	-0.3090	0.7690	0.5590
4016	0.0290	0.0503	74.0000	-0.3090	0.9140	0.2621
4017	0.0295	0.0578	180.0000	-0.3090	0.0000	-0.9511
4018	0.0290	0.0578	352.0000	-0.3090	-0.1324	0.9418
4019	0.0295	0.0656	72.0000	-0.3090	0.9045	0.2939
4020	0.0290	0.1086	0.0000	-0.3090	0.0000	0.9511
4021	0.0310	0.1086	45.0000	-0.3090	0.6725	0.6725
626	0.0320	0.0440	0.0000	0.0000	0.0000	1.0000
5103	0.0320	0.6250	0.0000	0.0000	0.0000	1.0000
4023	0.0315	0.1265	46.0000	0.0000	0.7193	0.6947
4024	0.0300	0.3906	260.0000	0.0000	-0.9850	-0.1736
4025	0.0300	0.5990	0.0000	0.0000	0.0000	1.0000
4026	0.0295	0.5990	99.0000	0.0000	0.9877	-0.1564
4027	0.0300	0.5990	279.0000	0.0000	-0.9877	0.1564
4028	0.0320	0.9540	18.0000	-0.3201	0.2928	0.9010
3224	0.0324	0.0462	45.0000	-0.3090	-0.6725	0.6725
3226	0.0290	0.1086	90.0000	-0.3090	0.9511	0.0000
3227	0.0295	0.1502	180.0000	0.0000	0.0000	-1.0000
3228	0.0290	0.1518	144.0000	0.0000	-0.5878	-0.8090
3229	0.0285	0.1680	105.0000	0.0000	-0.9659	-0.2588
3230	0.0310	0.1623	324.0000	0.0000	0.5878	0.8090
3231	0.0326	0.1651	330.0000	0.0000	0.5000	0.8660
3232	0.0290	0.2385	135.0000	0.0000	-0.7071	-0.7071
3233	0.0285	0.4240	180.0000	0.0000	0.0000	-1.0000
3234	0.0295	0.6090	180.0000	0.0000	0.0000	-1.0000
3235	0.0295	0.7420	0.0000	0.0000	0.0000	1.0000
3236	0.0280	0.7420	90.0000	0.0000	-1.0000	0.0000
3237	0.0300	0.8330	0.0000	0.0000	0.0000	1.0000
3238	0.0285	0.9720	45.0000	-0.3201	-0.6699	0.6699
3239	0.0290	0.9910	95.0000	-0.3201	-0.9438	-0.0826
3240	0.0306	0.9910	315.0000	-0.3200	0.6699	0.6699
4208	0.0300	0.0462	6.0000	-0.3090	0.0994	0.9458
4209	0.0290	0.0462	90.0000	-0.3090	-0.9511	0.0000
4210	0.0290	0.0462	270.0000	-0.3090	-0.9511	0.0000
4211	0.0320	0.1086	10.0000	-0.3090	0.1651	0.9366
4212	0.0300	0.1518	0.0000	0.0000	0.0000	1.0000
4213	0.0295	0.1518	140.0000	0.0000	0.6428	-0.7660
4214	0.0300	0.1623	110.0000	0.0001	0.9397	-0.3420
4215	0.0300	0.1651	330.0000	0.0000	-0.5000	0.8660
4216	0.0300	0.2385	225.0000	0.0000	-0.7071	-0.7071
4217	0.0350	0.4240	180.0000	0.0000	0.0000	-1.0000
4218	0.0295	0.6090	180.0000	0.0000	0.0000	-1.0000
4219	0.0300	0.7420	180.0000	0.0000	0.0000	-1.0000

4220	0.0300	0.8330	180.0000	0.0000	0.0000	-1.0000
4221	0.0310	0.9720	90.0000	-0.3201	0.9474	0.0000
4222	0.0310	0.9720	135.0000	-0.3201	0.6679	-0.6679
4223	0.0315	0.9720	166.0000	-0.3201	0.2292	-0.9193
5030	0.0315	0.0760	174.0000	-0.4790	0.0920	-0.8730
5031	0.0324	0.0760	264.0000	-0.4790	-0.8730	-0.0920
5033	0.0325	0.1871	270.0000	-0.1440	-0.9900	0.0000
5034	0.0320	0.2700	270.0000	0.0000	-1.0000	0.0000
5246	0.0314	0.0760	25.0000	-0.5020	0.3650	0.7840
5247	0.0324	0.1871	8.2500	-0.1440	0.1420	0.9790
5248	0.0290	0.2700	0.0000	0.0000	0.0000	1.0000
5045	0.0315	0.6295	172.5000	0.0000	0.1310	-0.9910
5046	0.0305	0.6295	264.4000	0.0000	-0.9950	-0.0980
5047	0.0325	0.9078	168.8000	0.0000	0.1940	-0.9810
5048	0.0323	0.9156	5.6000	0.0000	0.0980	0.9950
5049	0.0300	0.9275	356.3000	0.0000	-0.0650	0.9980
5050	0.0300	0.9373	5.6000	0.0000	0.0980	0.9950
5051	0.0300	0.9373	276.0000	0.0000	-0.9950	0.1050
5052	0.0305	0.9373	340.6000	0.0000	-0.3320	0.9430
5249	0.0300	0.4350	0.0000	0.0000	0.0000	1.0000
5250	0.0300	0.4440	358.0000	0.0000	-0.0350	0.9990
5251	0.0310	0.6300	352.5000	0.0000	-0.1310	0.9910
5252	0.0327	0.8370	310.0000	0.0000	-0.7660	0.6430
983	0.0296	0.0257	0.0000	-0.6830	0.0000	0.7760
600	0.0344	0.0366	0.0000	-0.5970	0.0000	0.8020
601	0.0336	0.0501	0.0000	-0.5570	0.0000	0.8310
5152	0.0315	0.0664	0.0000	-0.5080	0.0000	0.8620
5153	0.0308	0.0826	0.0000	-0.4590	0.0000	0.8890
5154	0.0313	0.0257	25.0000	-0.6330	0.3280	0.7040
5155	0.0332	0.0414	25.0000	-0.5830	0.3430	0.7360
5156	0.0331	0.0507	25.0000	-0.5550	0.3520	0.7540
5157	0.0300	0.0604	25.0000	-0.5260	0.3600	0.7710
5158	0.0328	0.0805	25.0000	-0.4650	0.3740	0.8020
5159	0.0328	0.0913	25.0000	-0.4320	0.3810	0.8170
5160	0.0400	0.4300	17.0000	0.0000	0.2920	0.9560
5161	0.0400	0.4300	343.1200	0.0000	-0.2900	0.9570
5162	0.0319	0.4468	20.0000	0.0000	0.3420	0.9400
5163	0.0310	0.4609	20.0000	0.0000	0.3420	0.9400
629	0.0310	0.4550	0.0000	0.0000	0.0000	1.0000
5165	0.0310	0.4609	331.0000	0.0000	-0.4850	0.8750
5166	0.0310	0.4755	20.0000	0.0000	0.3420	0.9400
5167	0.0310	0.4755	332.0000	0.0000	-0.4690	0.8830
5168	0.0305	0.4896	20.0000	0.0000	0.3420	0.9400
5169	0.0310	0.4896	331.0000	0.0000	-0.4850	0.8750
5170	0.0330	0.8261	332.0000	0.0000	-0.4690	0.8830
5171	0.0328	0.8364	18.0000	0.0000	0.3090	0.9510
5172	0.0330	0.8402	331.0000	0.0000	-0.4850	0.8750
5173	0.0337	0.8607	20.0000	0.0000	0.3420	0.9400
627	0.0315	0.4450	0.0000	0.0000	0.0000	1.0000
630	0.0310	0.4600	0.0000	0.0000	0.0000	1.0000
5176	0.0330	0.8786	20.0000	0.0000	0.3420	0.9400
5177	0.0326	0.8786	358.0000	0.0000	-0.0350	0.9990
5178	0.0327	0.8786	331.0000	0.0000	-0.4850	0.8750
5179	0.0326	0.8922	18.0000	0.0000	0.3090	0.9510
5180	0.0327	0.8960	332.0000	0.0000	-0.4690	0.8830
5185	0.0295	0.9274	48.0000	0.0000	0.7430	0.6690
5072	0.0400	0.2900	280.0000	0.0000	-0.9850	0.1740
5073	0.0400	0.3000	280.0000	0.0000	-0.9850	0.1740

TABLE 3. Continued

5074	0.0400	0.3100	280.0000	0.0000	-0.9850	0.1740
5075	0.0400	0.3200	280.0000	0.0000	-0.9850	0.1740
5076	0.0400	0.3300	280.0000	0.0000	-0.9850	0.1740
5077	0.0400	0.3400	280.0000	0.0000	-0.9850	0.1740
5078	0.0400	0.3500	280.0000	0.0000	-0.9850	0.1740
5079	0.0400	0.3600	280.0000	0.0000	-0.9850	0.1740
5080	0.0400	0.3700	280.0000	0.0000	-0.9850	0.1740
5081	0.0400	0.3850	280.0000	0.0000	-0.9850	0.1740
5082	0.0400	0.3950	337.5000	0.0000	-0.3830	0.9240
5083	0.0305	0.4700	337.5000	0.0000	-0.3830	0.9240
5084	0.0305	0.5000	337.5000	0.0000	-0.3830	0.9240
5085	0.0400	0.3950	330.0000	0.0000	-0.5000	0.8660
5086	0.0400	0.4310	330.0000	0.0000	-0.5000	0.8660
5087	0.0400	0.3950	343.1200	0.0000	-0.2900	0.9570
5088	0.0400	0.3900	40.0000	0.0000	0.6430	0.7660
635	0.0295	0.5500	0.0000	0.0000	0.0000	1.0000
5109	0.0329	0.8800	270.0000	0.0000	-1.0000	0.0000
5110	0.0329	0.8800	255.0000	0.0000	-0.9660	-0.2590
5111	0.0310	0.9380	315.0000	0.0000	-0.7070	0.7070
5112	0.0285	0.9380	0.0000	0.0000	0.0000	1.0000
5113	0.0305	0.9380	23.0000	0.0000	0.3910	0.9210
5114	0.0329	0.8800	240.0000	0.0000	-0.8660	-0.5000
5115	0.0330	0.8800	285.0000	0.0000	-0.9660	0.2590
5118	0.0305	0.9260	240.0000	0.0000	-0.8660	-0.5000
5119	0.0310	0.9260	285.0000	0.0000	-0.9660	0.2590
5120	0.0285	0.9380	15.0000	0.0000	0.2590	0.9660
5121	0.0305	0.9380	240.0000	0.0000	-0.8660	-0.5000
5122	0.0305	0.9380	345.0000	0.0000	-0.2590	0.9660
5123	0.0335	0.8000	58.5000	0.0000	0.8530	0.5220
5124	0.0337	0.8400	58.5000	0.0000	0.8530	0.5220
634	0.0310	0.5000	0.0000	0.0000	0.0000	1.0000
5126	0.0290	0.9260	58.5000	0.0000	0.8530	0.5220
5127	0.0340	0.8000	68.0000	0.0000	0.9270	0.3750
5128	0.0340	0.8400	68.0000	0.0000	0.9270	0.3750
5129	0.0339	0.8800	68.0000	0.0000	0.9270	0.3750
5130	0.0300	0.9260	68.0000	0.0000	0.9270	0.3750
5131	0.0339	0.8000	75.0000	0.0000	0.9660	0.2590
5132	0.0340	0.8400	75.0000	0.0000	0.9660	0.2590
5133	0.0338	0.8800	75.0000	0.0000	0.9660	0.2590
5134	0.0280	0.9260	75.0000	0.0000	0.9660	0.2590
5504	0.0400	0.4300	32.0000	0.0000	0.5300	0.8480
5508	0.0305	0.4590	32.0000	0.0000	0.5300	0.8480
5512	0.0310	0.4940	32.0000	0.0000	0.5300	0.8480
5515	0.0315	0.5640	32.0000	0.0000	0.5300	0.8480
5534	0.0337	0.8790	38.0000	0.0000	0.6160	0.7880
5535	0.0338	0.8790	32.0000	0.0000	0.5300	0.8480
5537	0.0310	0.4650	27.0000	0.0000	0.4540	0.8910
633	0.0310	0.4900	0.0000	0.0000	0.0000	1.0000
5539	0.0341	0.8500	27.0000	0.0000	0.4540	0.8910
5253	0.0321	0.1750	18.0000	-0.1800	0.3040	0.9360
5254	0.0323	0.2000	180.0000	-0.1050	0.0000	-0.9950
632	0.0310	0.4800	0.0000	0.0000	0.0000	1.0000
5257	0.0325	0.3100	270.0000	0.0000	-1.0000	0.0000
5258	0.0315	0.3400	270.0000	0.0000	-1.0000	0.0000
628	0.0310	0.4500	0.0000	0.0000	0.0000	1.0000
631	0.0310	0.4700	0.0000	0.0000	0.0000	1.0000
3261	0.0322	0.0150	90.0000	-0.3090	-0.9511	0.0000
4063	0.5040	0.9460	280.0000	-1.0000	0.0000	0.0000

4064	0.5000	0.9460	180.0000	-1.0000	0.0000	0.0000
4065	0.5320	0.9460	0.0000	-1.0000	0.0000	0.0000
3066	0.5000	0.9460	48.0000	-1.0000	0.0000	0.0000
3067	0.4420	0.9470	35.0000	0.0000	-0.5736	0.8192
3068	0.4520	0.9460	42.0000	-1.0000	0.0000	0.0000
4069	0.4500	0.7530	0.0000	-1.0000	0.0000	0.0000
4070	0.5560	0.7530	98.0000	-1.0000	0.0000	0.0000
4071	0.4500	0.7530	180.0000	-1.0000	0.0000	0.0000
3203	0.5280	0.7570	50.0000	-1.0000	0.0000	0.0000
3207	0.5340	0.1450	270.0000	-0.5000	0.8660	0.0000
4186	0.5220	0.9620	16.0000	-0.4435	0.0000	0.8963
5029	0.5250	0.0120	180.0000	-0.6350	0.0000	-0.7730
5032	0.6120	0.1871	180.0000	-0.1440	0.0000	-0.9900
5035	0.5700	0.3328	180.0000	0.0000	0.0000	-1.0000
5036	0.5000	0.3328	251.4000	0.0000	-0.9480	-0.3190
5037	0.4780	0.3328	270.0000	0.0000	-1.0000	0.0000
5038	0.4200	0.3328	288.6000	0.0000	-0.9480	0.3190
5039	0.5040	0.4179	2.5000	0.0000	0.0440	0.9990
5040	0.5120	0.4103	2.5000	0.0000	0.0440	0.9990
5041	0.4920	0.4244	2.5000	0.0000	0.0440	0.9990
5042	0.5500	0.3515	25.0000	0.0000	0.4230	0.9060
5043	0.5600	0.3831	270.0000	0.0000	-1.0000	0.0000
5044	0.5800	0.4090	180.0000	0.0000	0.0000	-1.0000
5181	0.5500	0.0574	37.7000	-0.7350	0.4150	0.5370
5241	0.5650	0.0560	31.3100	-0.8240	0.2960	0.4830
5259	0.5640	0.4730	37.5000	0.0000	0.6090	0.7830
5260	0.4460	0.4710	35.0000	0.0000	0.5740	0.8190
5053	0.5340	0.3690	23.0000	-0.4300	-0.7970	0.4240
5054	0.4840	0.3620	25.0000	-0.6000	0.3380	0.7250
5055	0.4880	0.5450	27.5000	0.0000	0.6090	0.7930
5056	0.5120	0.8600	37.5000	0.0000	0.6090	0.7930
5057	0.5180	0.4350	0.0000	-1.0000	0.0000	0.0000
5058	0.4860	0.3328	270.0000	-1.0000	0.0000	0.0000
5059	0.4440	0.9070	320.0000	-0.4820	0.0000	0.8760
5060	0.5200	0.9370	17.0000	-1.0000	0.0000	0.0000
5061	0.4620	0.9310	33.0000	-1.0000	0.0000	0.0000
5062	0.5120	0.9070	25.0000	-1.0000	0.0000	0.0000
5540	0.5120	0.8500	32.0000	0.0000	0.5300	0.8480
5242	0.5100	0.0400	180.0000	-0.5870	0.0000	-0.8090
3243	0.4120	0.0000	90.0000	-1.0000	0.0000	0.0000

TABLE 4. Phase B Instrumentation and Constants

Gage T/C No.	Skin Thickness (in.)	X/L	θ (deg)	N_X	N_Y	N_Z
3001	0.0295	0.1990	90.0000	0.0000	-1.0000	0.0000
3002	0.0300	0.1990	135.0000	0.0000	-0.7070	-0.7070
3003	0.0300	0.1990	180.0000	0.0000	0.0000	-1.0000
3004	0.0290	0.4980	90.0000	0.0000	-1.0000	0.0000
3005	0.0290	0.4980	180.0000	0.0000	0.0000	-1.0000
4013	0.0285	0.0000	0.0000	-1.0000	0.0000	-1.0000
4014	0.0285	0.0081	0.0000	-0.3090	0.0000	0.9510
4015	0.0290	0.0497	54.0000	-0.3090	0.7690	0.5590
4016	0.0290	0.0503	74.0000	-0.3090	0.9140	0.2621
4017	0.0295	0.0578	180.0000	-0.3090	0.0000	-0.9511
4018	0.0290	0.0578	352.0000	-0.3090	-0.1324	0.9418
4019	0.0295	0.0656	72.0000	-0.3090	0.9045	0.2939
4020	0.0290	0.1086	0.0000	-0.3090	0.0000	0.9511
4021	0.0310	0.1086	45.0000	-0.3090	0.6725	0.6725
4023	0.0315	0.1265	46.0000	0.0000	0.7193	0.6947
4024	0.0300	0.3906	260.0000	0.0000	-0.9850	-0.1736
4025	0.0300	0.5990	0.0000	0.0000	0.0000	1.0000
4026	0.0295	0.5990	99.0000	0.0000	0.9877	-0.1564
4027	0.0300	0.5990	279.0000	0.0000	-0.9877	0.1564
3224	0.0324	0.0462	45.0000	-0.3090	-0.6725	0.6725
3226	0.0290	0.1086	90.0000	-0.3090	0.9511	0.0000
4208	0.0300	0.0462	6.0000	-0.3090	0.0994	0.9458
4209	0.0290	0.0462	90.0000	-0.3090	-0.9511	0.0000
4210	0.0290	0.0462	270.0000	-0.3090	-0.9511	0.0000
5030	0.0315	0.0760	174.0000	-0.4790	0.0920	-0.8730
5031	0.0324	0.0760	264.0000	-0.4790	-0.8730	-0.0920
5033	0.0325	0.1871	270.0000	-0.1440	-0.9900	0.0000
5034	0.0320	0.2700	270.0000	0.0000	-1.0000	0.0000
5246	0.0314	0.0760	25.0000	-0.4790	0.4200	0.7710
5247	0.0324	0.1871	8.2500	-0.1440	0.1420	0.9790
5248	0.0290	0.2700	0.0000	0.0000	0.0000	1.0000
5045	0.0315	0.6295	172.5000	0.0000	0.1310	-0.9910
5046	0.0305	0.6295	264.4000	0.0000	-0.9950	-0.0980
5047	0.0325	0.9078	168.8000	0.0000	0.1940	-0.9810
5048	0.0323	0.9156	5.6000	0.0000	0.0980	0.9950
5049	0.0300	0.9275	356.3000	0.0000	-0.0650	0.9980
5050	0.0300	0.9373	5.6000	0.0000	0.0980	0.9950
5051	0.0300	0.9373	276.0000	0.0000	-0.9950	0.1050
5052	0.0305	0.9373	340.6000	0.0000	-0.3320	0.9430
5249	0.0300	0.4350	0.0000	0.0000	0.0000	1.0000
5250	0.0300	0.4440	358.0000	0.0000	-0.0350	0.9990
5251	0.0310	0.6300	352.5000	0.0000	-0.1310	0.9910
5252	0.0327	0.8370	310.0000	0.0000	-0.7660	0.6430
5156	0.0331	0.0507	25.0000	-0.5550	0.3520	0.7540
699	0.0326	0.0500	29.8000	-0.5570	0.4130	0.7210
715	0.0326	0.0500	37.7000	-0.5570	0.5080	0.6570
5072	0.0400	0.2900	280.0000	0.0000	-0.9850	0.1740
5073	0.0400	0.3000	280.0000	0.0000	-0.9850	0.1740
5074	0.0400	0.3100	280.0000	0.0000	-0.9850	0.1740
5075	0.0400	0.3200	280.0000	0.0000	-0.9850	0.1740
5076	0.0400	0.3300	280.0000	0.0000	-0.9850	0.1740
5077	0.0400	0.3400	280.0000	0.0000	-0.9850	0.1740
5078	0.0400	0.3500	280.0000	0.0000	-0.9850	0.1740
5079	0.0400	0.3600	280.0000	0.0000	-0.9850	0.1740
5080	0.0400	0.3700	280.0000	0.0000	-0.9850	0.1740
5081	0.0400	0.3850	280.0000	0.0000	-0.9850	0.1740
5082	0.0400	0.3950	337.5000	0.0000	-0.3830	0.9240

5083	0.0305	0.4700	337.5000	0.0000	-0.3830	0.9240
5084	0.0305	0.5000	337.5000	0.0000	-0.3830	0.9240
5085	0.0400	0.3950	330.0000	0.0000	-0.5000	0.8660
5086	0.0400	0.4310	330.0000	0.0000	-0.5000	0.8660
5087	0.0400	0.3950	343.1200	0.0000	-0.2900	0.9570
5088	0.0400	0.3900	40.0000	0.0000	0.6430	0.7660
5096	0.0300	0.5500	17.0000	0.0000	0.2920	0.9560
5097	0.0300	0.5500	11.8000	0.0000	0.3390	0.9410
635	0.0295	0.5500	0.0000	0.0000	0.0000	1.0000
5099	0.0295	0.5500	348.0000	0.0000	-0.2080	0.9780
5100	0.0295	0.5500	337.5000	0.0000	-0.3830	0.9240
5101	0.0320	0.6250	17.0000	0.0000	0.2920	0.9560
5102	0.0320	0.6250	11.8000	0.0000	0.2040	0.9790
5103	0.0320	0.6250	0.0000	0.0000	0.0000	1.0000
696	0.0320	0.9260	17.0000	0.0000	0.2920	0.9560
5104	0.0310	0.6250	348.0000	0.0000	-0.2080	0.9780
5105	0.0305	0.6250	337.5000	0.0000	-0.3830	0.9240
5106	0.0300	0.6650	337.5000	0.0000	-0.3830	0.9240
5107	0.0300	0.6650	330.0000	0.0000	-0.5000	0.8660
5108	0.0290	0.6650	315.0000	0.0000	-0.7070	0.7070
5109	0.0329	0.8800	270.0000	0.0000	-1.0000	0.0000
5110	0.0329	0.8800	255.0000	0.0000	-0.9660	-0.2590
5111	0.0310	0.9380	315.0000	0.0000	-0.7070	0.7070
5112	0.0285	0.9380	0.0000	0.0000	0.0000	1.0000
5113	0.0305	0.9380	23.0000	0.0000	0.3910	0.9210
5114	0.0329	0.8800	240.0000	0.0000	-0.8660	-0.5000
5115	0.0330	0.8800	285.0000	0.0000	-0.9660	0.2590
5118	0.0305	0.9260	240.0000	0.0000	-0.8660	-0.5000
5119	0.0310	0.9260	285.0000	0.0000	-0.9660	0.2590
5120	0.0285	0.9380	15.0000	0.0000	0.2590	0.9660
5121	0.0305	0.9380	240.0000	0.0000	-0.8660	-0.5000
5122	0.0305	0.9380	345.0000	0.0000	-0.2590	0.9660
5123	0.0335	0.8000	58.5000	0.0000	0.8530	0.5220
5124	0.0337	0.8400	58.5000	0.0000	0.8530	0.5220
5126	0.0290	0.9260	58.5000	0.0000	0.8530	0.5220
5127	0.0340	0.8000	68.0000	0.0000	0.9270	0.3750
5128	0.0340	0.8400	68.0000	0.0000	0.9270	0.3750
5129	0.0339	0.8800	68.0000	0.0000	0.9270	0.3750
5130	0.0300	0.9260	68.0000	0.0000	0.9270	0.3750
5131	0.0339	0.8000	75.0000	0.0000	0.9660	0.2590
5132	0.0340	0.8400	75.0000	0.0000	0.9660	0.2590
5133	0.0338	0.8800	75.0000	0.0000	0.9660	0.2590
5134	0.0280	0.9260	75.0000	0.0000	0.9660	0.2590
2072	0.0400	0.4200	36.3200	0.0000	0.5920	0.8060
5502	0.0400	0.4200	32.0000	0.0000	0.5300	0.8480
2073	0.0400	0.4250	36.3200	0.0000	0.5920	0.8060
5504	0.0400	0.4300	32.0000	0.0000	0.5300	0.8480
2074	0.0400	0.4300	36.3200	0.0000	0.5920	0.8480
5506	0.0310	0.4510	32.0000	0.0000	0.5300	0.8480
5508	0.0305	0.4590	32.0000	0.0000	0.5300	0.8480
5512	0.0310	0.4940	32.0000	0.0000	0.5300	0.8480
5513	0.0330	0.5560	32.0000	0.0000	0.5300	0.8480
5515	0.0315	0.5640	32.0000	0.0000	0.5300	0.8480
5516	0.0315	0.5910	32.0000	0.0000	0.5300	0.8480
2085	0.0335	0.6000	33.7500	0.0000	0.5560	0.8310
5518	0.0305	0.6260	32.0000	0.0000	0.5300	0.8480
5519	0.0330	0.6340	32.0000	0.0000	0.5300	0.8480
5501	0.0325	0.6610	38.0000	0.0000	0.6160	0.7880

5520	0.0330	0.6610	32.0000	0.0000	0.5300	0.8480
5503	0.0325	0.6690	38.0000	0.0000	0.6160	0.7880
5521	0.0330	0.6690	32.0000	0.0000	0.5300	0.8480
5505	0.0320	0.6960	38.0000	0.0000	0.6160	0.7880
5522	0.0320	0.6960	32.0000	0.0000	0.5300	0.8480
709	0.0341	0.7000	29.8000	0.0000	0.4970	0.8680
5507	0.0320	0.7040	38.0000	0.0000	0.6160	0.7880
5523	0.0320	0.7040	32.0000	0.0000	0.5300	0.8480
5524	0.0337	0.7390	38.0000	0.0000	0.6160	0.7880
5525	0.0337	0.7390	32.0000	0.0000	0.5300	0.8480
5509	0.0338	0.7660	38.0000	0.0000	0.6160	0.7880
5526	0.0337	0.7660	32.0000	0.0000	0.5300	0.8480
5511	0.0339	0.7740	38.0000	0.0000	0.6160	0.7880
5527	0.0338	0.7740	32.0000	0.0000	0.5300	0.8480
710	0.0339	0.8000	29.8000	0.0000	0.4970	0.8680
726	0.0339	0.8000	37.7000	0.0000	0.6120	0.7910
5528	0.0337	0.8010	32.0000	0.0000	0.5300	0.8480
5529	0.0343	0.8090	32.0000	0.0000	0.5300	0.8480
5530	0.0337	0.8360	32.0000	0.0000	0.5300	0.8480
5531	0.0336	0.8440	32.0000	0.0000	0.5300	0.8480
711	0.0336	0.8700	29.8000	0.0000	0.4970	0.8680
727	0.0336	0.8700	37.7000	0.0000	0.6120	0.7910
5533	0.0335	0.8710	32.0000	0.0000	0.5300	0.8480
5534	0.0337	0.8790	38.0000	0.0000	0.6160	0.7880
5535	0.0338	0.8790	32.0000	0.0000	0.5300	0.8480
5536	0.0310	0.4590	27.0000	0.0000	0.4540	0.8910
5537	0.0310	0.4650	27.0000	0.0000	0.4540	0.8910
2055	0.0345	0.8400	45.0000	0.0000	0.7070	0.7070
2056	0.0345	0.8500	45.0000	0.0000	0.7070	0.7070
5538	0.0343	0.8440	27.0000	0.0000	0.4540	0.8910
5539	0.0341	0.8500	27.0000	0.0000	0.4540	0.8910
5253	0.0321	0.1750	18.0000	-0.1800	0.3040	0.9360
5254	0.0323	0.2000	180.0000	-0.1050	0.0000	-0.9950
5257	0.0325	0.3100	270.0000	0.0000	-1.0000	0.0000
5258	0.0315	0.3400	270.0000	0.0000	-1.0000	0.0000
626	0.0320	0.0440	0.0000	0.0000	0.0000	1.0000
628	0.0310	0.4500	0.0000	0.0000	0.0000	1.0000
629	0.0310	0.4550	358.0000	0.0000	-0.3500	1.0000
631	0.0310	0.4700	0.0000	0.0000	0.0000	1.0000
632	0.0310	0.4800	0.0000	0.0000	0.0000	1.0000
633	0.0310	0.4900	0.0000	0.0000	0.0000	1.0000
634	0.0310	0.5000	0.0000	0.0000	0.0000	1.0000
2008	0.0310	0.5810	31.4300	0.0000	0.5210	0.8530
2140	0.0300	0.9260	289.4000	0.0000	-0.9430	0.3320
2145	0.0295	0.9300	289.4000	0.0000	-0.9430	0.3320
2146	0.0300	0.9300	270.0000	0.0000	-1.0000	0.0000
3261	0.0322	0.0150	90.0000	-0.3090	-0.9511	0.0000
4063	0.5040	0.9460	280.0000	-1.0000	0.0000	0.0000
4064	0.5000	0.9460	180.0000	-1.0000	0.0000	0.0000
4065	0.5320	0.9460	0.0000	-1.0000	0.0000	0.0000
3066	0.5000	0.9460	48.0000	-1.0000	0.0000	0.0000
3067	0.4420	0.9470	35.0000	0.0000	-0.5736	0.8192
3068	0.4520	0.9460	42.0000	-1.0000	0.0000	0.0000
4069	0.4500	0.7530	0.0000	-1.0000	0.0000	0.0000
4070	0.5560	0.7530	98.0000	-1.0000	0.0000	0.0000
4071	0.4500	0.7530	180.0000	-1.0000	0.0000	0.0000
3203	0.5280	0.7570	50.0000	-1.0000	0.0000	0.0000
3207	0.5340	0.1450	270.0000	-0.5000	0.8660	0.0000

4186	0.5220	0.9620	16.0000	-0.4435	0.0000	0.8963
5029	0.5250	0.0120	180.0000	-0.6350	0.0000	-0.7730
5032	0.6120	0.1871	180.0000	-0.1440	0.0000	-0.9900
5035	0.5700	0.3328	180.0000	0.0000	0.0000	-1.0000
5036	0.5000	0.3328	251.4000	0.0000	-0.9480	-0.3190
5037	0.4780	0.3328	270.0000	0.0000	-1.0000	0.0000
5038	0.4200	0.3328	288.6000	0.0000	-0.9480	0.3190
5039	0.5040	0.4179	2.5000	0.0000	0.0440	0.9990
5040	0.5120	0.4103	2.5000	0.0000	0.0440	0.9990
5041	0.4920	0.4244	2.5000	0.0000	0.0440	0.9990
5042	0.5500	0.3515	25.0000	0.0000	0.4230	0.9060
5043	0.5600	0.3831	270.0000	0.0000	-1.0000	0.0000
5044	0.5800	0.4090	180.0000	0.0000	0.0000	-1.0000
5241	0.5650	0.0560	31.3100	-0.8240	0.2960	0.4830
5259	0.5640	0.4730	37.5000	0.0000	0.6090	0.7830
5260	0.4460	0.4710	35.0000	0.0000	0.5740	0.8190
5053	0.5340	0.3690	23.0000	-0.4300	-0.7970	0.4240
5054	0.4840	0.3620	25.0000	-0.6000	0.3380	0.7250
5055	0.4880	0.5450	37.5000	0.0000	0.6090	0.7930
5056	0.5120	0.8600	37.5000	0.0000	0.6090	0.7930
5057	0.5180	0.4350	0.0000	-1.0000	0.0000	0.0000
5058	0.4860	0.3328	270.0000	-1.0000	0.0000	0.0000
5059	0.4440	0.9070	320.0000	-0.4820	0.0000	0.8760
5060	0.5200	0.9370	17.0000	-1.0000	0.0000	0.0000
5061	0.4620	0.9310	330.0000	-1.0000	0.0000	0.0000
5062	0.5120	0.9070	25.0000	-1.0000	0.0000	0.0000
5540	0.5120	0.8500	32.0000	0.0000	0.5300	0.8980
5242	0.5100	0.0400	180.0000	-0.5870	0.0000	0.0000
3243	0.4120	0.0000	90.0000	-1.0000	0.0000	0.0000
4187	0.5150	0.9600	314.4800	0.0000	0.7036	0.7106
4188	0.6180	0.9540	292.5900	-1.0000	0.0000	0.0000
4190	0.6480	0.9600	88.8000	-0.3201	0.9472	0.0198
4191	0.5250	0.9540	247.1000	-1.0000	0.0000	0.0000

TABLE 5. Schmidt-Boelter Gage Calibration Constants

GAGE SENSITIVITY TO INCIDENT RADIANT FLUX
(ABSORPTIVITY = 0.97)

GAGE No.	C_1 SENSITIVITY mv/Btu/ft^{2}sec	GAGE No.	C_1 SENSITIVITY mv/Btu/ft^{2}sec
5062	.512	5044	.580
5061	.462	5054	.484
5035	.570	3203	.528
5032	.612	4071	.450
5036	.500	5058	.486
3207	.534	5242	.510
4188	.618	4191	.525
5042	.550	3068	.452
3243	.412	4187	.515
4186	.522	5060	.520
5540	.512	3066	.500
5053	.534	4190	.634
4069	.450	5241	.565
5037	.478	4064	.500
5059	.444	5057	.518
5056	.512	5029	.525
5055	.488	5181	.550
3067	.442	5041	.492
5039	.504	5040	.512
5260	.446	5259	.564
4070	.556	4063	.504
5038	.420	5043	.560
4189	.545	4065	.532

VKF TUNNEL A TEST LOG

TABLE 6 Run Summary

PAGE 1 OF 7

USER: ROCKWELL INTERNATIONAL

PROJECT TITLE: NASA/RI IH-97 (PHASE A)

PROJECT: C767VA (V--A-1X)

DATE: 10/18/82

REPRESENTATIVE(S): JOHN MARROQUIN / GENE KNOX, DICK LEEF / DEXTER WONG

MODEL: 60-OTS

TEST PERSONNEL: W.K. CRAIN / K.W. NUTT

Run	Configuration Code	RE/ft x106	M	PT psia	TT °F	ALPHA deg	BETA deg	DELTA-E (deg)	DELTA-BF (deg)	DELTA-SB (deg)			Remarks
1, 2	OTS+Tr	3.7	3.00	34	220	0	0	10	0	0			
3													NO INJECTION
4		4.0	2.25	23	190	2.4	-0.6						
5						2.6	0.8						
6						1.8	-0.7						
7						0.6	-0.2						
8			2.50	26		3.2	-0.6						
9						2.8	0.8						
10						1.6	-0.7						
11						1.5	0.2						
12			2.75	31		3.8	-0.6						
13						3.6	1.3						
14						0.9	-0.8						
15						0.2	0.1						
16		3.7	3.00	34	220	0	0	0					

NOMENCLATURE

VKF TUNNEL A TEST LOG

TABLE 6. Continued

PAGE 2 OF 7	
USER: ROCKWELL INTERNATIONAL	PROJECT TITLE: NASA/RI IH-97 (PHASE A)
REPRESENTATIVE(S): JOHN MARROQUIN / GENE KNOX, DICK LEEF / DEXTER WONG	MODEL: 60-OTS
PROJECT: C767VA (V--A-1X)	DATE: 10/18/82
TEST PERSONNEL: W.K. CRAIN / K.W. NUTT	

Run	Configuration Code	RE/FT x10^6	M	PT psia	TT °F	ALPHA deg	BETA deg	DELTA-E (deg)	DELT-BF (deg)	DELT-SB (deg)			Remarks
17	OTS+Tr	3.7	3.00	37	262	4.5	-0.7	0	0	0			
18						4.6	1.3						
19						1.6	-0.7						
20						0.2	-0.1						
21						0	3						
22							-3						
23						5	0						
24							3						
25							-3						
26		3.9	3.25	45		4.4	-0.6						
27						5.2	1.7						
28						1.5	-0.7						
29						0.3	0						
30		4.0	3.50	55		4.5	-0.4						
31						5.3	1.5						
32						1.4	0.2						
33						0.4	-0.3						

NOMENCLATURE

VKF TUNNEL A TEST LOG

TABLE 6. Continued

USER	PROJECT TITLE	PROJECT	DATE
ROCKWELL INTERNATIONAL	NASA/RI IH-97 (PHASE A)	C767VA (V--A-1X)	10/18/82
REPRESENTATIVE(S): JOHN MARROQUIN / GENE KNOX, DICK LEEF / DEXTER WONG	MODEL: 60-OTS	TEST PERSONNEL: W.K. CRAIN / K.W. NUTT	

Run	Configuration Code	$Re/FT \times 10^6$	M	PT psia	TT °F	ALPHA deg	BETA deg	DELTA-E (deg)	DELT-BF (deg)	DELT-SB (deg)			Remarks
34	OTS+Tr	4.00	3.75	62	280	0.3	0	0	0	0			
35						1.5	-0.5						
36						3.9	0.7						
37						5.0	0.1						
38			4.00	73		0.7	-0.6						
39						0	0						

NOMENCLATURE

VKF TUNNEL A TEST LOG

TABLE 6. Continued

USER	PROJECT TITLE	PROJECT	DATE
ROCKWELL INTERNATIONAL	NASA/RI IH-97 (PHASE B)	C767VA (V--A-1X)	10/19/82
REPRESENTATIVE(S)	MODEL	TEST PERSONNEL	
JOHN MARROQUIN / GENE KNOX DICK LEEF / DEXTER WONG	60-OTS	W.K. CRAIN / K.W. NUTT	

Run	Configuration Code	RE/FT x10^6	M	PT psia	TT °F	ALPHA deg	BETA deg	DELTA-E (deg)	DELT-BF (deg)	DELT-SB (deg)			Remarks
40	OTS+Tr+TVC	3.7	3.00	37	262	5.00	0	0	0	0			
41							3						
42							-3						
43							6						
44							-6						
45						0	0						
46							3						
47							-3						
48							6						
49							-6						
50						-5	0						
51							3						
52							-3						
53							6						
54							-6						
55						0	-3						REPEAT OF RUN 47

NOMENCLATURE

VKF TUNNEL A **TEST LOG**

TABLE 6. Continued

PAGE 5 OF 7

USER: ROCKWELL INTERNATIONAL

REPRESENTATIVE(S): JOHN MARROQUIN / GENE KNOX, DICK LEEF / DEXTER WONG

PROJECT TITLE: NASA/RI IH-97 (PHASE B)

MODEL: 60-OTS

PROJECT: C767VA (V--A-1X)

DATE: 10/19/82

TEST PERSONNEL: W.K. CRAIN / K.W. NUTT

Run	Configuration Code	RE/FT x10^6	M	PT psia	TT °F	ALPHA deg	BETA deg	DELTA-E (deg)	DELTA-BF (deg)	DELTA-SB (deg)		Remarks
56	OTS+TVC	3.7	3.00	37	262	0	0	0	0	0		TRIPS OFF SRB'S
57	OTS+Tr+TVC	3.9	3.25	45	270	0	0					TRIPS BACK ON SRB'S
58							-3					
59						5	0					
60		4.0	3.50	55		0	0					
61						1.4	-0.2					
62						0	-3.0					
63						5.0	0.0					
64			3.75	62		0	0					
65							-3					
66						5	0					
67						1.5	-0.5					REPEAT OF RUN 35
68			4.00	73		0	0					

NOMENCLATURE

VKF TUNNEL A TEST LOG

TABLE 6. Continued

PAGE 6 OF 7

USER	PROJECT TITLE	PROJECT	DATE
ROCKWELL INTERNATIONAL	NASA/RI IH-97 (PHASE B)	C767VA (V--A-1X)	10/19/82
REPRESENTATIVE(S): JOHN MARROQUIN / GENE KNOX, DICK LEEF / DEXTER WONG	MODEL: 60-OTS	TEST PERSONNEL: W.K. CRAIN / K.W. NUTT	

Run	Configuration Code	Re/FT x10^6	M	PT psia	TT °F	ALPHA deg	BETA deg	DELTA-E (deg)	DELTA-BF (deg)	DELTA-SB (deg)			Remarks
69	OTS+Tr+TVC	4.00	4.00	73	270	5.0	0	0	0	0			
70							3						
71							-3						
72							6						
73							-6						
74						0	3						
75							-3						
76							6						
77							-6						
78						-5	0						
79							3						
80							-3						
81							6						
82							-6						

NOMENCLATURE

VKF TUNNEL A TEST LOG

TABLE 6. Concluded

USER	PROJECT TITLE	PROJECT	DATE
ROCKWELL INTERNATIONAL	NASA/RI IH-97 (PHASE B)	C767VA (V--A-1X)	10/18/82
REPRESENTATIVE(S): JOHN MARROQUIN/GENE KNOX, DICK LEEF /DEXTER WONG	MODEL: 60-OTS	TEST PERSONNEL: W.K. CRAIN/K.W. NUTT	

Run	Configuration Code	RE/FT $\times 10^{6}$	M	PT psia	TT °F	ALPHA deg	BETA deg	DELTA-E (DEG)	DELTA-BF (deg)	DELTA-SB (deg)			Remarks
83	OTS+TVC	4.00	4.00	73	270	0	0	0	0	0			TRIPS OFF SRB's
84	OTS+Tr+TVC							10					TRIPS BACK ON SRB's
85		5.6	3.00	52	220								

NOMENCLATURE

TABLE 7. Photographic Summary

Camera	Camera Type	Type Photography	Roll No.	Run No.
1	Varitron 70 mm Still	Shadowgraph	0521	1 - 39
			0518	40 - 63
				70 - 85
		Color Schlieren	0508	64 - 69

APPENDIX III

REFERENCE HEAT-TRANSFER COEFFICIENTS

In presenting heat-transfer coefficient results it is convenient to use reference coefficients to normalize the data. Equilibrium stagnation point values derived from the work of Fay and Riddell* were used to normalize the data obtained in this test. These reference coefficients are given by:

$$H(REF) = \frac{8.17173(PT2)^{1/2}(MUTT)^{0.4}\left[1 - \frac{P}{PT2}\right]^{0.25}\left[0.2235 + (1.35 \times 10^{-5})(TT+560)\right]}{(RN)^{1/2}(TT)^{0.15}}$$

and

$$STFR = \frac{H(REF)}{(RHO)(V)\ \left[0.2235 + (1.35 \times 10^{-5})(TT + 560)\right]}$$

where

PT2	Stagnation pressure downstream of a normal shock wave, psia
MUTT	Air viscosity based on TT, $lb_f\text{-sec/ft}^2$
P	Free-stream pressure, psia
TT	Tunnel stilling chamber temperature, °R
RN	Reference nose radius, (0.0175 ft)
RHO	Free-stream density, lbm/ft^3
V	Free-stream velocity, ft/sec

*Fay, J. A. and Riddell, F. R. "Theory of Stagnation Point Heat Transfer in Dissociated Air," Journal of the Aeronautical Sciences, Vol. 25, No. 2, February 1958.

APPENDIX IV

SAMPLE TABULATED DATA

AEDC DIVISION
VON KARMAN G DYNAMICS FACILITY
ARNOLD AIR F CE STATION, TENNESSEE
NASA/RI IH97 HEATING TEST
PAGE 1

TIME COMPUTED 17:06:16
DATE RECORDED 18-OCT-82
TIME RECORDED 14:13:55
PROJECT NUMBER V4 A-1X

RUN	PHASE	MODEL	MACH NO	PT,PSIA	TT,DEGR	ALPHA-SECTOR	ROLL-SECTOR	ALPHA	YAW
2	A	60-OTS	3.01	33.9	677.7	-0.02	0.00	-0.02	0.00

T (DEGR)	P (PSIA)	Q (PSIA)	V (FT/SEC)	RHO (LBM/FT3)	MU (LB-SEC/FT2)	RE (FT-1)	H(REF) (RN= .0175FT)	STFR (RN= .0175FT)	DELTAE	DELTBF	DELTSB
240.99	0.910	5.773	2291.	1.019E-02	1.932E-07	3.757E+06	5.285E-02	9.421E-03	10.	0.	0.

TC NO	TW (DEGR)	DTW/DT (DEG/S)	QDOT (BTU/FT2-S)	H(TT) (BTU/FT2-S-DEGR)	H(TT) /HREF	H(.95TT) (BTU/FT2-S-DEGR)	H(.95TT) /HREF	R	H(RTT) BTU/FT2-S-DEGR)	H(RTT) /HREF	THERMOCOUPLE LOCATIONS X/L	THETA	SKIN THICKNESS (IN)
											R/H SRB		
3002	512.3	3.771	4.997E-01	3.021E-03	0.0572	3.7999E-03	0.0719	0.934	4.1414E-03	0.0784	0.199	135.000	0.030
3003	513.5	4.409	5.846E-01	3.561E-03	0.0674	4.4878E-03	0.0849	0.934	4.8952E-03	0.0926	0.199	180.000	0.030
3004	511.5	2.686	3.439E-01	2.070E-03	0.0392	2.5999E-03	0.0492	0.934	2.8320E-03	0.0536	0.498	90.000	0.029
3005	520.9	3.672	4.724E-01	3.013E-03	0.0570	3.8430E-03	0.0727	0.934	4.2147E-03	0.0798	0.498	180.000	0.029
3006	530.7	5.304	6.858E-01	4.667E-03	0.0883	6.0663E-03	0.1148	0.934	6.7099E-03	0.1270	0.692	90.000	0.029
3007	576.1	4.560	6.449E-01	6.347E-03	0.1201	9.5225E-03	0.1802	0.940	1.0627E-02	0.2011	0.974	4.000	0.031
3008	528.5	3.549	4.978E-01	3.338E-03	0.0632	4.3188E-03	0.0817	0.940	4.5999E-03	0.0870	0.988	90.000	0.032
3009	544.3	1.239	1.780E-01	1.335E-03	0.0253	1.7903E-03	0.0339	0.940	1.9269E-03	0.0365	0.988	135.000	0.032
3010	557.8	2.152	3.015E-01	2.515E-03	0.0476	3.5061E-03	0.0663	0.934	4.0119E-03	0.0759	0.988	182.000	0.031
3011	551.2	5.511	7.449E-01	5.891E-03	0.1115	8.0482E-03	0.1523	0.940	8.7114E-03	0.1648	0.988	270.000	0.030
3012	533.3	6.398	8.569E-01	5.936E-03	0.1123	7.7573E-03	0.1468	0.940	8.2854E-03	0.1568	0.994	53.000	0.030
											L/H SRB		
4013	564.9	15.713	2.052E+00	2.211E-02	0.4184	3.4830E-02	0.6591	1.000	2.2118E-02	0.4185	0.000	0.000	0.029
4014	545.0	16.026	2.051E+00	1.546E-02	0.2926	2.0766E-02	0.3929	0.939	2.2427E-02	0.4244	0.008	0.000	0.029
4015	530.7	12.071	1.561E+00	1.062E-02	0.2010	1.3803E-02	0.2612	0.939	1.4759E-02	0.2793	0.050	54.000	0.029
4016	535.4	13.723	1.779E+00	1.250E-02	0.2365	1.6406E-02	0.3104	0.939	1.7594E-02	0.3329	0.050	74.000	0.029
4017	540.9	12.734	1.684E+00	1.231E-02	0.2329	1.6359E-02	0.3095	0.939	1.7614E-02	0.3333	0.058	180.000	0.029
4018	525.1	9.913	1.278E+00	8.377E-03	0.1585	1.0768E-02	0.2038	0.939	1.1476E-02	0.2171	0.058	352.000	0.029
4019	525.2	9.119	1.196E+00	7.841E-03	0.1484	1.0081E-02	0.1908	0.939	1.0744E-02	0.2033	0.066	72.000	0.029
4020	530.2	11.386	1.472E+00	9.980E-03	0.1889	1.2958E-02	0.2452	0.939	1.3850E-02	0.2621	0.109	0.000	0.029
4021	527.4	11.851	1.635E+00	1.088E-02	0.2059	1.4046E-02	0.2658	0.939	1.4989E-02	0.2836	0.109	45.000	0.031
4023	524.8	7.117	9.966E-01	6.521E-03	0.1234	8.3789E-03	0.1585	0.934	9.2193E-03	0.1744	0.126	46.000	0.032
4024	497.6	3.977	5.229E-01	2.904E-03	0.0549	3.5767E-03	0.0677	0.934	3.8632E-03	0.0731	0.391	260.000	0.030
4025	526.0	5.505	7.346E-01	4.842E-03	0.0916	6.2351E-03	0.1180	0.934	6.8671E-03	0.1299	0.599	0.000	0.030
4026	521.1	1.966	2.573E-01	1.643E-03	0.0311	2.0961E-03	0.0397	0.934	2.2992E-03	0.0435	0.599	99.000	0.029
4027	512.1	3.580	4.743E-01	2.864E-03	0.0542	3.6007E-03	0.0681	0.934	3.9237E-03	0.0742	0.599	279.000	0.030
4028	552.8	6.650	9.595E-01	7.682E-03	0.1454	1.0542E-02	0.1995	0.940	1.1425E-02	0.2162	0.954	18.000	0.032
											SRB ACREAGE		
3224	528.8	16.543	2.387E+00	1.604E-02	0.3035	2.0764E-02	0.3929	0.939	2.2175E-02	0.4196	0.046	45.000	0.032
3226	562.5	20.093	2.640E+00	2.291E-02	0.4336	3.2460E-02	0.6142	0.939	3.5673E-02	0.6750	0.109	90.000	0.029
3227	505.0	4.139	5.373E-01	3.112E-03	0.0589	3.8720E-03	0.0733	0.934	4.2002E-03	0.0795	0.150	180.000	0.029
3228	517.2	5.527	7.096E-01	4.421E-03	0.0837	5.6043E-03	0.1060	0.934	6.1291E-03	0.1160	0.152	144.000	0.029
3229	504.1	3.202	4.013E-01	2.312E-03	0.0437	2.8724E-03	0.0544	0.934	3.1141E-03	0.0589	0.168	105.000	0.029
3230	503.5	3.321	4.527E-01	2.600E-03	0.0492	3.2276E-03	0.0611	0.934	3.4980E-03	0.0662	0.162	324.000	0.031
3231	507.0	3.635	5.219E-01	3.057E-03	0.0578	3.8141E-03	0.0722	0.934	4.1423E-03	0.0784	0.165	330.000	0.033
3232	514.8	3.494	4.480E-01	2.750E-03	0.0520	3.4723E-03	0.0657	0.934	3.7909E-03	0.0717	0.239	135.000	0.029
3233	520.1	5.186	6.554E-01	4.158E-03	0.0787	5.2972E-03	0.1002	0.934	5.8059E-03	0.1099	0.424	180.000	0.029
3234	531.6	3.263	4.294E-01	2.940E-03	0.0556	3.8280E-03	0.0724	0.934	4.2377E-03	0.0802	0.609	180.000	0.029
											SRB ACREAGE		
3235	553.9	8.510	1.133E+00	9.147E-03	0.1731	1.2592E-02	0.2383	0.934	1.4319E-02	0.2709	0.742	0.000	0.029

Thin Skin Thermocouples

VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI IH97 HEATING TEST
PAGE 6

TIME COMPUTED 17:06:19
DATE RECORDED 18-OCT-82
TIME RECORDED 14:13:55
PROJECT NUMBER V4 A-1X

RUN	PHASE	MODEL	MACH NO	PT,PSIA	TT,DEGR	ALPHA-SECTOR	ROLL-SECTOR	ALPHA	YAW
2	A	60-OTS	3.01	33.9	677.7	-0.02	0.00	-0.02	0.00

T (DEGR)	P (PSIA)	Q (PSIA)	V (FT/SEC)	RHO (LBM/FT3)	MU (LB-SEC/FT2)	RE (FT-1)	H(REF) (RN= .0175FT)	STFR (RN= .0175FT)	DELTAE	DELTBF	DELTSB
240.99	0.910	5.773	2291.	1.019E-02	1.932E-07	3.757E+06	5.285E-02	9.421E-03	10.	0.	0.

GAGE NO	TW (DEGR)	QDOT (BTU/FT2-S)	H(TT) (BTU/FT2-S-DEGR)	H(TT) /HREF	H(.95TT) (BTU/FT2-S-DEGR)	H(.95TT) /HREF	R	H(RTT) BTU/FT2-S-DEGR)	H(RTT) /HREF	THERMOCOUPLE LOCATIONS X/L	THETA	SKIN THICKNESS (IN)
										PROTUBERANCE		
4063	543.8	2.548E+00	1.904E-02	0.3603	2.5497E-02	0.4824	1.000	1.9041E-02	0.3603	0.946	280.000	
4064	557.7	7.310E-01	6.090E-03	0.1152	8.4861E-03	0.1606	1.000	6.0903E-03	0.1152	0.946	180.000	
4065	548.4	2.335E+00	1.806E-02	0.3417	2.4476E-02	0.4631	1.000	1.8061E-02	0.3417	0.946	0.000	
3066	540.9	2.603E-01	1.903E-03	0.0360	2.5298E-03	0.0479	1.000	1.9030E-03	0.0360	0.946	48.000	
3067	554.2	4.173E-01	3.379E-03	0.0639	4.6569E-03	0.0881	0.934	5.2980E-03	0.1002	0.947	35.000	
3068	548.2	9.020E-02	6.966E-04	0.0132	9.4343E-04	0.0179	1.000	6.9657E-04	0.0132	0.946	42.000	
4069	530.3	4.179E+00	2.836E-02	0.5366	3.6825E-02	0.6966	1.000	2.8356E-02	0.5366	0.753	0.000	
4070	581.7	1.015E+00	1.058E-02	0.2001	1.6349E-02	0.3094	1.000	1.0576E-02	0.2001	0.753	98.000	
4071	539.5	2.614E+00	1.892E-02	0.3580	2.5068E-02	0.4743	1.000	1.8920E-02	0.3580	0.753	180.000	
3203	579.0	7.617E+00	7.721E-02	1.4611	1.1761E-01	2.2254	1.000	7.7214E-02	1.4611	0.757	50.000	
3207	514.3	3.202E+00	1.961E-02	0.3710	2.4740E-02	0.4681	0.949	2.4907E-02	0.4713	0.145	270.000	
4186	546.8	4.581E+00	3.501E-02	0.6625	4.7245E-02	0.8940	0.945	4.8827E-02	0.9239	0.962	16.000	
										ET OFI LOCATIONS		
5029	567.8	6.079E+00	5.531E-02	1.0466	7.9963E-02	1.5131	0.959	7.4225E-02	1.4045	0.012	180.000	
5032	501.1	1.073E+00	6.073E-03	0.1149	7.5148E-03	0.1422	0.935	8.0915E-03	0.1531	0.187	180.000	
5035	502.7	4.525E-01	2.586E-03	0.0489	3.2077E-03	0.0607	0.934	3.4746E-03	0.0658	0.333	180.000	
5036	557.3	1.493E+00	1.240E-02	0.2346	1.7255E-02	0.3265	0.934	1.9727E-02	0.3733	0.333	251.400	
5037	580.0	2.030E+00	2.078E-02	0.3932	3.1809E-02	0.6019	0.934	3.8319E-02	0.7251	0.333	270.000	
5038	558.2	1.553E+00	1.300E-02	0.2460	1.8147E-02	0.3434	0.934	2.0779E-02	0.3932	0.333	288.600	
5039	540.9	1.323E+00	9.674E-03	0.1831	1.2860E-02	0.2433	0.934	1.4375E-02	0.2720	0.418	2.500	
5040	535.4	1.030E+00	7.245E-03	0.1371	9.5104E-03	0.1800	0.934	1.0568E-02	0.2000	0.410	2.500	
5041	549.7	1.432E+00	1.118E-02	0.2116	1.5209E-02	0.2878	0.934	1.7189E-02	0.3252	0.424	2.500	
5042	511.4	4.155E-01	2.498E-03	0.0473	3.1376E-03	0.0594	0.934	3.4174E-03	0.0647	0.352	25.000	
5043	513.4	3.161E-01	1.925E-03	0.0364	2.4248E-03	0.0459	0.934	2.6448E-03	0.0500	0.383	270.000	
5044	508.0	3.803E-01	2.242E-03	0.0424	2.8013E-03	0.0530	0.934	3.0445E-03	0.0576	0.409	180.000	

Schmidt-Boelter Gage